ERDC/CHL TR-12-11

Coastal and Hydraulics Laboratory

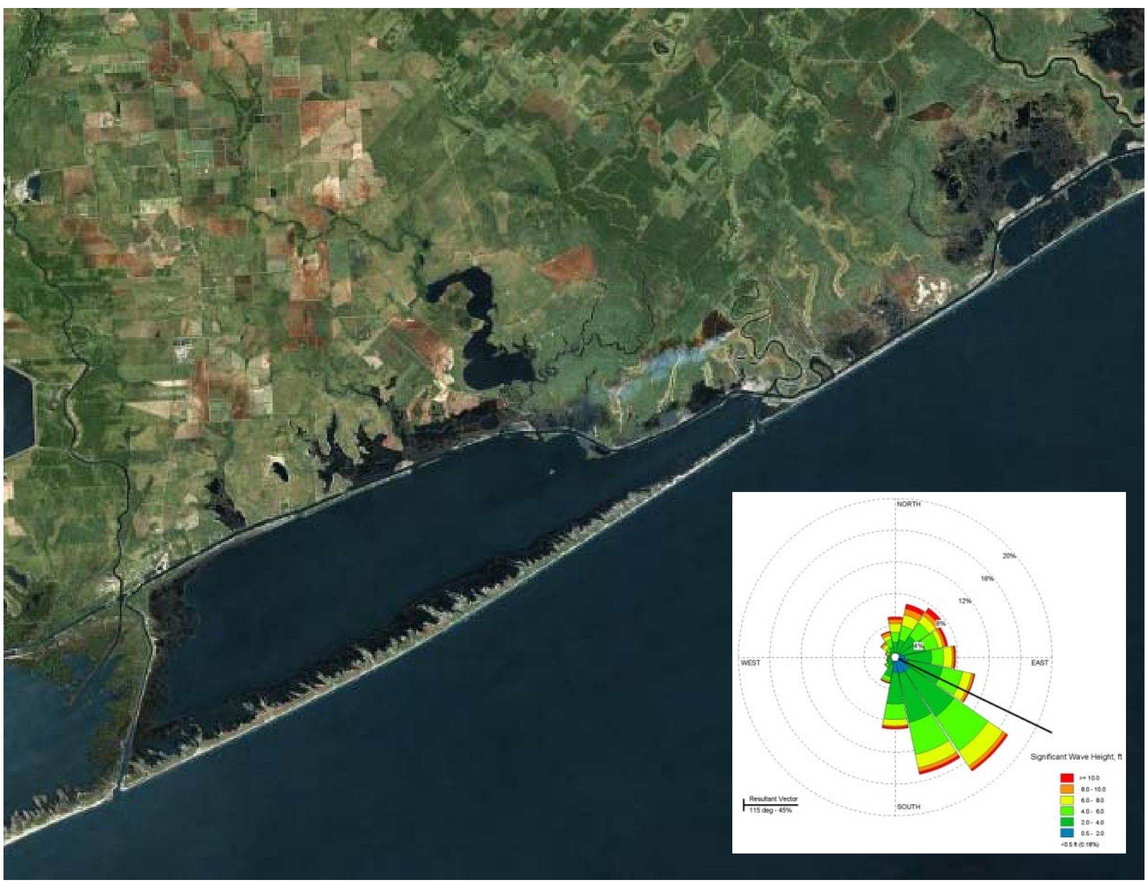
US Army Corps of Engineers®
Engineer Research and Development Center

Erosion Control and Environment Restoration Plan Development, Matagorda County, Texas

Phase 1: Preliminary Investigation

Robert Thomas and Lauren Dunkin

July 2012



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Phase 1: Preliminary Investigation

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Final report

Prepared for U.S. Army Corps of Engineers
P.O. Box 1229
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Abstract

This report documents the investigation of coastal processes and development of conceptual alternatives to reduce beach erosion at two sites in Matagorda County. Sargent Beach has experienced the greatest erosion rates on the Texas Coast, prompting study into structural methods to protect beach habitat. Additionally, the three miles of beach to the east of the Mouth of the Colorado River is a candidate for structural stabilization. The proximity of the two project areas provided an opportunity to consider processes on a regional scale in an effort to improve regional shoreline stability and further understanding of regional processes.

Sargent Beach is comprised of cohesive sediment overlain by a thin veneer of sand. It is located between an ephemeral inlet to the east and a flood relief inlet to the west. The region includes two major river diversion projects, an eight mile long revetment at Sargent Beach, and many other engineering modifications influencing transport. Because of the complex site, an investigation into coastal processes was conducted to determine alternative development. Understanding of physical processes developed during this investigation was applied to develop potential solutions to reduce erosion, including beach nourishment, groins, breakwaters, and installed bypassing systems.

Contents

Figures and Tables

Figures

Tables

Preface

This study was performed by the Coastal and Hydraulics Laboratory (CHL), funded by the U.S. Army Corps of Engineers, Galveston District (SWG) and Port of Bay City.

This report was prepared by Robert C. Thomas and Lauren M. Dunkin, Coastal Engineering Branch (CEB), of ERDC-CHL, Vicksburg, MS. The work described in the report was performed under the general administrative supervision of Dr. Jeffrey Waters, Chief of Coastal Engineering Branch, and Dr. Rose M. Kress, Chief of Navigation Division. Dr. Julie Dean Rosati, Dr. Lihwa Lin and Ashley E. Frey reviewed the report. Jose E. Sanchez and Dr. William D. Martin were Deputy Director and Director of CHL during the study and preparation of the report.

COL Kevin Wilson was ERDC Commander. Dr. Jeffrey Holland was ERDC Director.

Unit Conversion Factors

Multiply	By	To Obtain
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
feet	0.3048	meters
knots	0.5144444	meters per second
miles (nautical)	1,852	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
square feet	0.09290304	square meters
square miles	2.589998 E+06	square meters
yards	0.9144	meters

1 Introduction

1.1 Purpose

The Port of Bay City, Texas, requested assistance from U.S. Army Corps of Engineers to develop potential structural solutions to stop erosion of critical beach habitat and increase protection from tropical storms in Matagorda County. The two primary areas of concern are Sargent Beach and 2-3 miles of beach on Matagorda Peninsula, located approximately one mile east of the Mouth of the Colorado River (MCR) (Figure 1). Persistent erosion has threatened to breach Sargent Beach, which would have resulted in complete loss of beach habitat and impeded traffic on the Gulf Intracoastal Waterway (GIWW) if not for construction of a revetment in 1998. Figure A-1 in Appendix A shows regional features and key geographic locations.

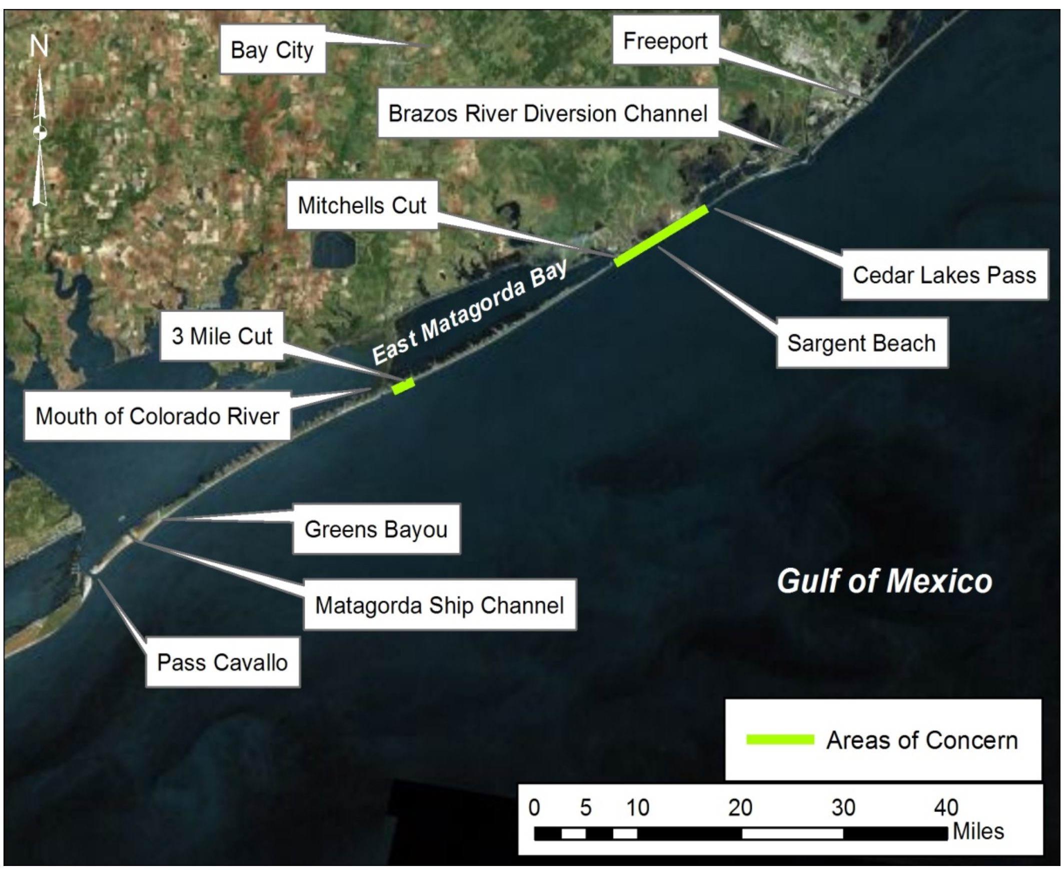

Figure 1. Map of project area and region.

The second area, east of the MCR, has been breached by ephemeral inlets in the past. A structural solution to reduce erosion of beaches in this region will protect beach habitat on Matagorda Peninsula, reduce storm damage, and reduce sediment impoundment along the MCR east jetty, reducing the need for future bypassing and maintenance dredging.

This report documents Phase 1 of a two-part analysis to help determine the feasibility of structural solutions to reduce erosion as requested by the Port of Bay City. Existing regional processes are investigated and preliminary solutions to reduce erosion are proposed and ranked to determine which alternatives should be analyzed in greater detail in Phase 2.

1.2 Project locations and history

Sargent Beach is located between Cedar Lakes and East Matagorda Bay on the Texas Gulf of Mexico coast; specifically, it is situated between an ephemeral inlet at Cedar Lakes to the east and the flood-relief Mitchells Cut to the west. The second site is located approximately 16 miles to the southwest of Mitchells Cut on Matagorda Peninsula, one mile to the east of MCR and directly to the west of 3 Mile Cut.

This section of the Texas Coast has been modified extensively since the early 1900s. The study sites are located between two major river diversion projects at the Brazos and Colorado Rivers. Changes to the sand transport regime caused by the river diversion projects are exacerbated by many other local construction projects, listed in Table 1, as well as periodic dredging at inlets for navigation. Physical processes have been in a constant state of change over the last 100 years as the regional system attempts to equilibrate after each alteration, making it difficult to predict the performance of new projects based on historic data. For example, Gibeaut et al. (2000) predicted that the shoreline at Sargent Beach would intersect the revetment by 2020 if the long-term trend continued; however, in some locations, the revetment crest is already within the swash zone at moderately high tides, as of the date of this publication (2011).

Mitchells Cut, an un-jettied pass to East Matagorda Bay dredged in 1989, has been relatively stable since construction[1]. Change in updrift sediment supply could result in destabilization of the pass, a critical feature to be considered during analysis of shore protection. After construction of the

[1] Mr. Charles Kalkomey, Jones and Carter, Inc., personal communication, 9/15/2011.

Table 1. Partial list of construction activities within the region.

Year	Activity
1929	Removal of a log jam on the Colorado River allowed a delta to prograde across East Matagorda Bay.
1929	Brazos River diverted from Freeport to present discharge location.
1936	Channel dredged to allow Colorado River to discharge directly to Gulf of Mexico (GOM).
1941	GIWW construction complete.
1966	Matagorda Ship Channel and jetties constructed across Matagorda Peninsula.
1989	Mitchells Cut dredged open to East Matagorda Bay to provide flood relief.
1990	Original MCR jetties constructed.
1992	Colorado River diverted into Matagorda Bay.
1998	Sargent Beach revetment constructed to protect GIWW.
2003	Sediment training structure constructed between MCR jetties.
2010	New east jetty constructed at MCR.

original MCR jetties in 1990, greater-than-anticipated transport led to greater dredging requirements and eventual effective closure of the inlet to navigation much of the year (Kraus et al. 2008). Construction of a new east jetty located between the existing jetties at MCR was completed in October 2010, with the intent to narrow the inlet thalweg and channelize flow. The inlet system has not reached equilibrium since construction of the new jetty; therefore, it may be necessary to reevaluate conditions at MCR after monitoring has been completed.

1.3 Previous studies

In 1994, USACE ERDC completed a study to evaluate erosion at Sargent Beach (Stauble et al. 1994). The study evaluated shoreline change and mechanisms of erosion in detail, leading to an evaluation of beach nourishment as an alternative to combat erosion. Stauble et al. (1994) reported that shoreline recession averaged 25 ft/year with locally higher rates up to 37 ft/year from 1943 to 1989 near McCabe's and Charpiot's Cut (see Figure A-1 for location); both have since been closed. Although data to adequately design beach nourishment on a partially cohesive beach were not available, nourishment was recommended as an alternative. The plan called for a three million cubic yard (cu yd) initial nourishment to cover approximately 10 miles with renourishment every four to five years. Adaptive management was recommended to ensure functionality.

Because of the many engineering projects in the region, coastal processes have been studied by many different authors, as well as the Federal government. Shoreline change in the region has been evaluated by Seelig and Sorenson (1973), Morton et al. (1976), Morton (1977), Kraus and Lin (2002), Kraus et al. (2008), and many others. Seelig and Sorenson (1973) presented a sediment budget for the region. Fields et al. (1988) analyzed sediment transport at the Brazos River, including estimates for sediment supply to the coast and evolution of the Brazos River delta.

A feasibility study was conducted by the U.S. Army Corps of Engineers (USACE 1993) to determine the preferred alternative for providing protection to the GIWW at Sargent Beach. This study resulted in construction of an 8-mile revetment and also provided detailed design information for the site. Preliminary design of breakwaters was completed in addition to design of the revetment.

1.4 Existing data

Existing data were gathered to enable preliminary analyses. New data will be collected during Phase 2 to fill critical data gaps. Table 2 lists some of the major data sources mined for this project.

1.5 Report organization

This report is organized in six chapters. Chapter 1 presents the project background and history. Chapter 2 discusses the site conditions. Chapter 3 presents the conceptual sediment budget. Chapter 4 documents GenCade model development. Preliminary alternatives are analyzed and ranked in Chapter 5. Chapter 6 provides a summary of this report and discusses work to be completed in Phase 2. Large format figures showing shoreline change, sediment budget layout, alternative layouts, and historical aerial imagery are included in the appendices; figures are plotted from north/east to south/west to match the GenCade direction convention.

Table 2. Summary of existing data sources.

Parameter	Source	Time Period
Waves	NOAA National Data Buoy Center (NDBC)	1990 - Present
	ERDC Wave Information Systems (WIS)	1980 - 2000
Water levels	FEMA Flood Insurance Study (FIS)	Extreme Events
	NOAA SLOSH model results	Extreme Events
	Texas Coastal Ocean Observation Network (TCOON)	Varies
	NOAA Center for Operational Oceanographic Products and Services (CO-OPS)	Varies
Sea Level Rise	NOAA Center for Operational Oceanographic Products and Services (CO-OPS)	Varies
Winds	Texas Coastal Ocean Observation Network (TCOON)	Varies
	NOAA Center for Operational Oceanographic Products and Services (CO-OPS)	Varies
	ERDC Wave Information Systems (WIS)	1980 - 2000
Shoreline Position	Texas Bureau of Economic Geology	1800s - 2000
Aerials	USACE ERDC Inlet Aerial Archive	1996-2011
	USDA	2004-2010
Surveys	USAED Galveston Channel Condition Surveys	Varies
	ERDC Beach Profiles	1990
	NOAA National Geophysical Data Center (NGDC)	Varies
	Coastal Tech Beach Profiles	2008, 2010
LIDAR	USACE JALBTCX	2009
Dredging Records	USAED Galveston	1943 - Present

2 Site Conditions

2.1 Water level

Water level on the Texas Coast is a function of tidal and wind forcing, exhibiting substantial seasonal variation. Nearby active tide stations are located at Port O'Connor, Freeport, and Galveston Island at the Pleasure Pier (see Figure A-1 inset for locations). Table 3 lists the elevation of tidal datums at Port O'Connor relative to the North American Vertical Datum 1988 (NAVD88). Greater diurnal tide range is 0.79 ft at Port O'Connor, 2.04 ft at Pleasure Pier, and 1.80 ft at Freeport. The tide station in the Colorado River Navigation Channel near the Mouth of the Colorado River (Rawlings) is also available for analysis from 1995 until it was destroyed by Hurricane Claudette in 2003, and has a greater diurnal tidal range of 1.33 ft. Because Port O'Connor and Rawlings are located inside Matagorda Bay, it is likely that the greater diurnal tide range along Matagorda Peninsula is closer to 1.80 ft. Figure 2 plots water level exceedance, showing the percent of time water level at the various tide stations exceeds any given elevation.

Extreme water levels associated with tropical storms should be anticipated during design. Table 4 lists the Federal Emergency Management Agency's (FEMA's) still water elevations as a function of return period near the project site relative to National Geodetic Vertical Datum 1929 (NGVD29), which is converted to NAVD88 for reference. Figure 3 plots model data from the NOAA SLOSH model showing the maximum of the maximum envelope of water level (MOM) for a Category 2 hurricane with a direct hit on the study area.

Table 3. Tidal datum elevations at Port O'Connor with respect to NAVD.

	Elevation above NAVD, ft
MHHW	0.30
MHW	0.28
NAVD	0.00
MSL	-0.09
MLW	-0.45
MLLW	-0.49

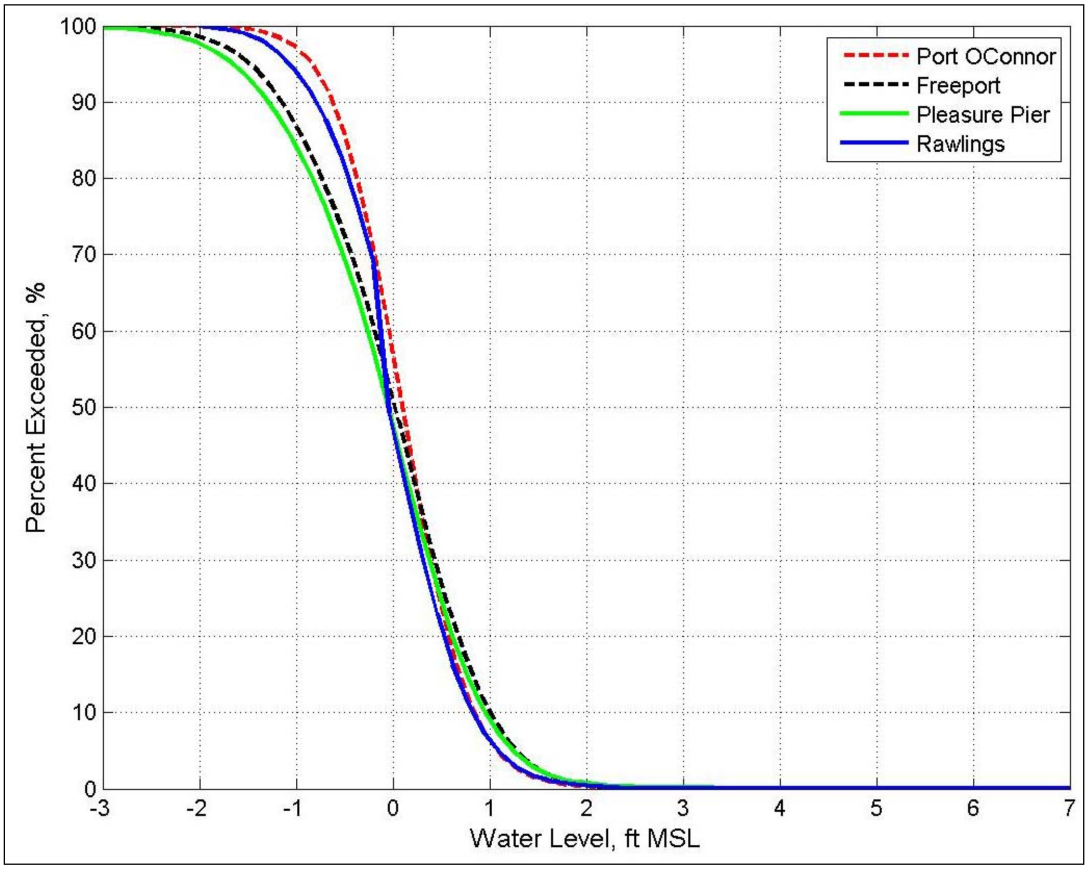

Figure 2. Percent of time water level is greater than the specified elevation for nearby tide stations.

Table 4. FEMA still water elevations with respect to NGVD29 and NAVD88.

	Still Water Elevations, ft (NGVD29)				Still Water Elevations, ft (NAVD88)			
	10-yr	50-yr	100-yr	500-yr	10-yr	50-yr	100-yr	500-yr
Sargent Beach (Transect 15)	4.65	7.84	8.83	10.77	4.52	7.71	8.7	10.64

Notes:

(1) Worst case still water elevations for transect taken from Matagorda County Flood Insurance Study

(2)Conversion from NGVD29 to NAVD88 based on CorpsCon near Sargent Beach.

2.2 Winds

Winds are a primary factor controlling water level and circulation along the Texas Coast as well as generating waves. Figures 4 and 5 represent the statistical distribution of winds at the Freeport and Port O'Connor tide stations. Winds from the south are most frequent. High winds from the north occur during the winter months and often result in extremely low water levels.

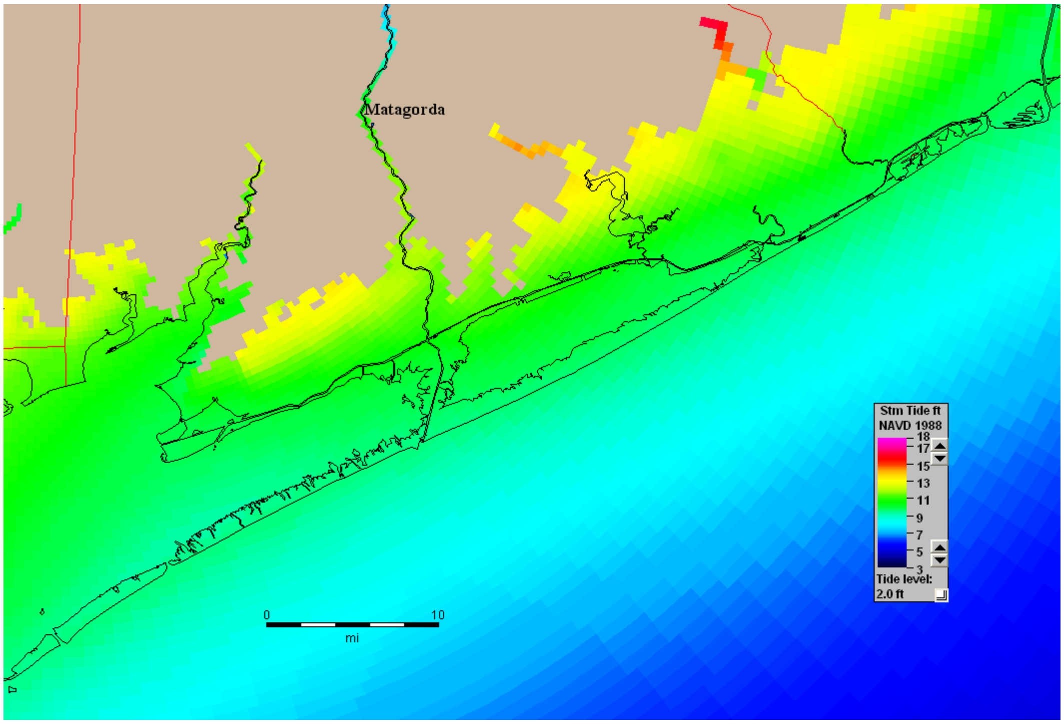

Figure 3. SLOSH model MOM for Category 2 storm with storm tide relative to NAVD88.

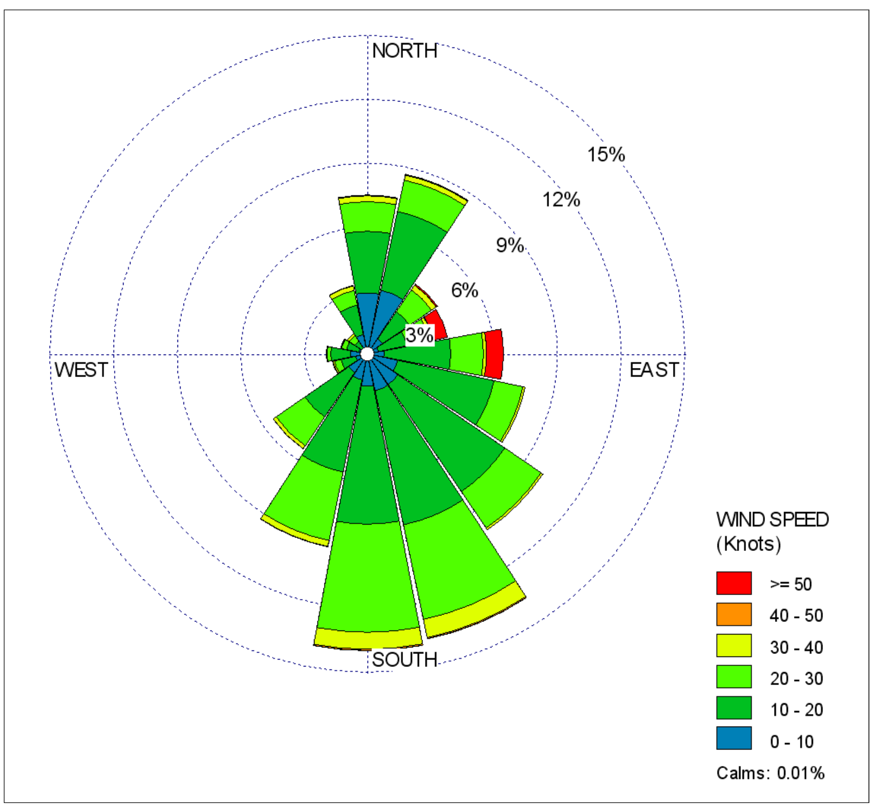

Figure 4. Wind rose at Freeport from 2007 – 2010.

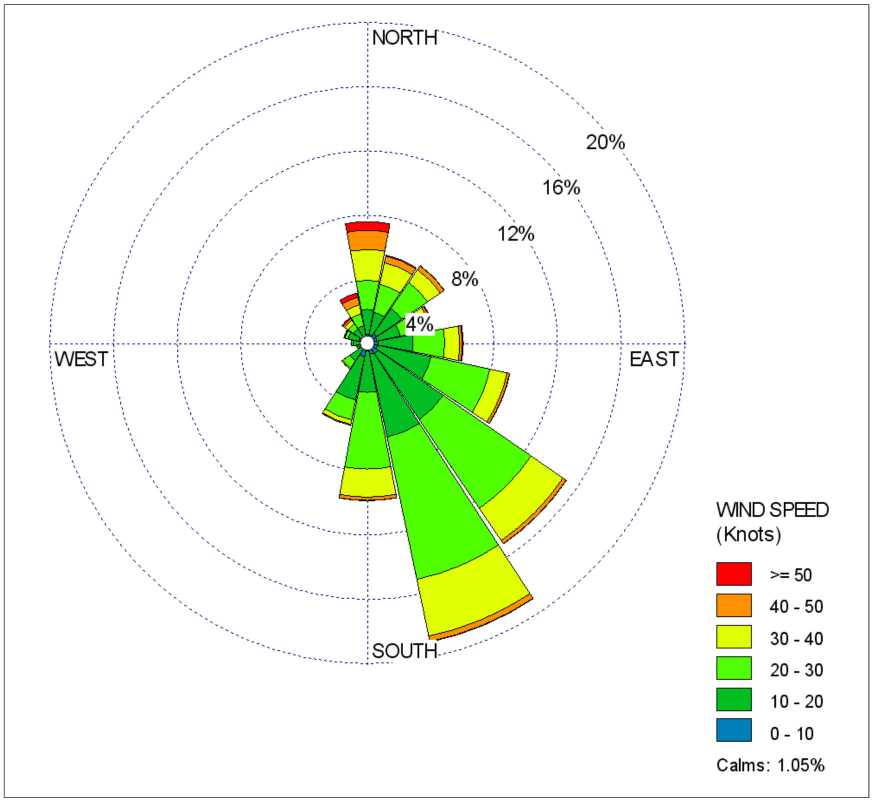

Figure 5. Wind rose at Port O'Connor from 2004 – 2010.

The greatest wind speeds in this region are associated with tropical storms. Table 5 lists extreme wind speed as a function of return period (American Society of Civil Engineers, ASCE 2010). Wind speed was converted from the 3-second gust reported to a 20 minute average duration to better represent winds acting over the representative fetch length for local wave estimation.

Table 5. Extreme wind speed as a function of return period.

	3 second gust, mph	20 minute average, mph
10-YR	80	54
25-YR	100	68
50-YR	110	75
100-YR	125	85

Note: Wind speed based on ASCE (2010).

2.3 Waves

Hindcast wave histories from WIS station 58 (28.5 °N, 95.58 °W) and WIS station 60 (28.58 °N, 95.50 °W) were analyzed to estimate the

probable significant wave height for the 50-year return period (Tracy 2004). The 50-year return period means that the wave has a two percent chance of being equaled or exceeded in any given year and a 64 percent chance of being equaled or exceeded in 50 years. Both stations are located at the 66-ft depth contour and have a 20 year record (1980-1999).

Data from the WIS stations were analyzed to determine the extreme waves for the 50-year return period. The 20-year data sets were sorted to determine the maximum wave height occurring during each storm event. Storm events were defined as any occurrence during which the wave height exceeded 12.5 ft at the WIS stations. This criterion was met by 30 storm events at WIS station 58 and 31 storm events at WIS station 60. The one additional storm event for WIS station 60 had a maximum wave height of 14.7 ft, which is one of the larger waves within the record. The wave height for the same storm event at WIS station 58 was only slightly lower than the 12.5-ft threshold, so this storm event was included in the analysis. The maximum wave height, associated period, and direction during the storm events are plotted in Figures 6, 7, and 8, respectively.

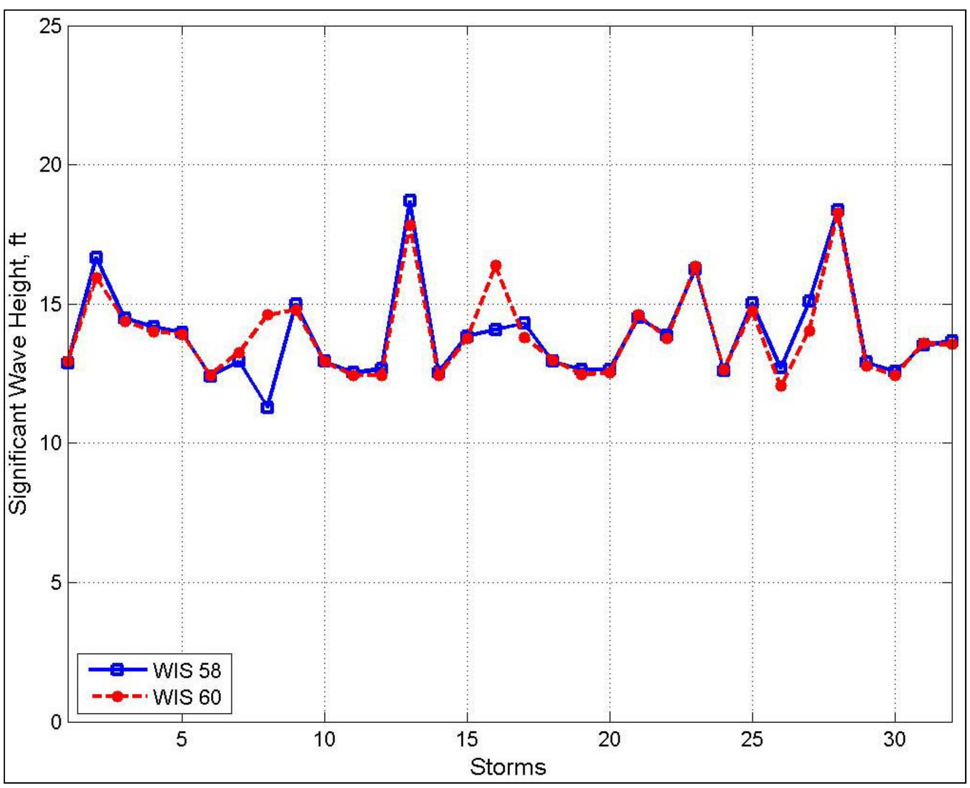

Figure 6. Peak storm wave height selected to analyze extreme waves.

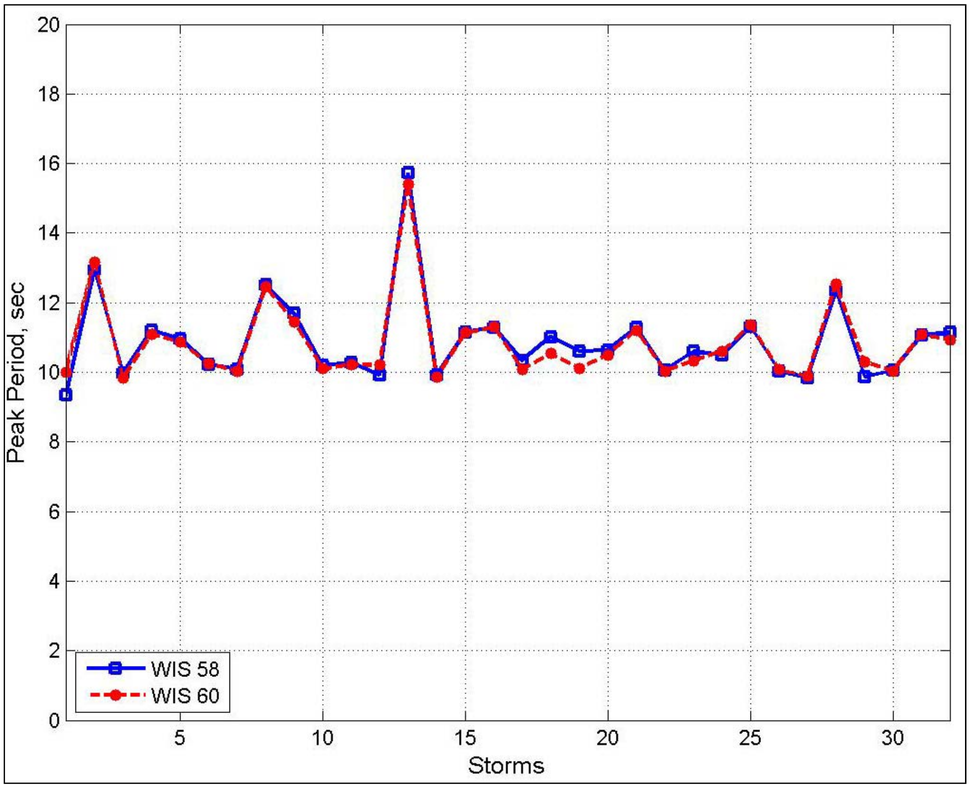

Figure 7. Peak storm wave period selected to analyze extreme waves.

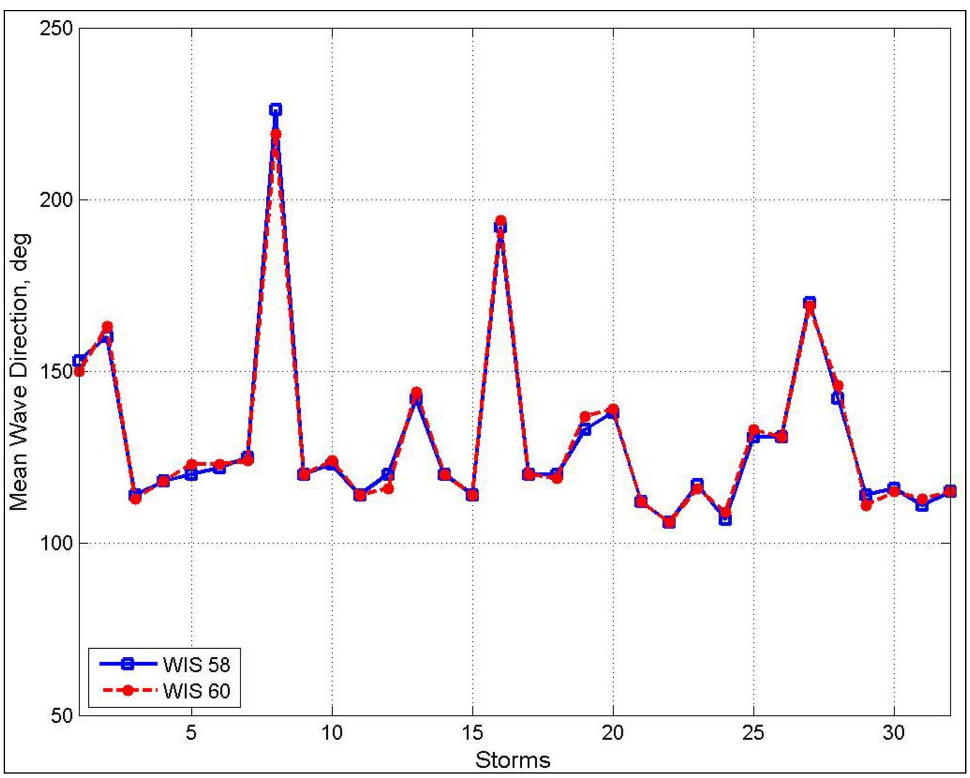

Figure 8. Peak storm wave direction selected to analyze extreme waves.

The offshore significant wave height for the two WIS stations for the 50-year return period is provided in Table 6. Wave period and direction were extracted from the wave record for the largest recorded waves. The 50-year return period extreme wave height for each station was found by fitting the wave heights from the storm events to a Weibull distribution. The distributions are provided in Figures 9 and 10.

Table 6. Wave parameters for the 50-year return period.

WIS Station	H_s, ft	T_p, sec	Direction, deg
WIS sta. 58	19.36	15.7	130
WIS sta. 60	19.02	15.4	130

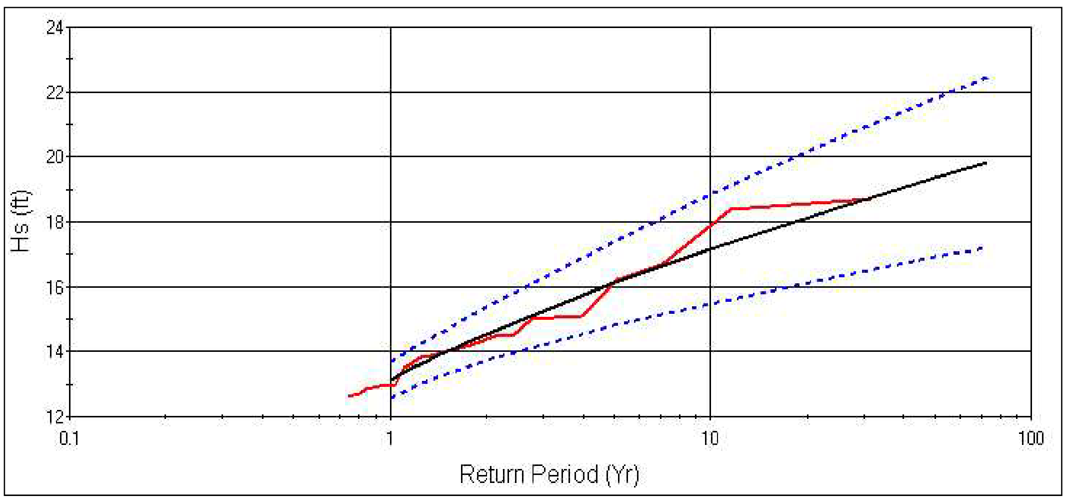

Figure 9. Extreme wave height analysis of data from WIS station 58.

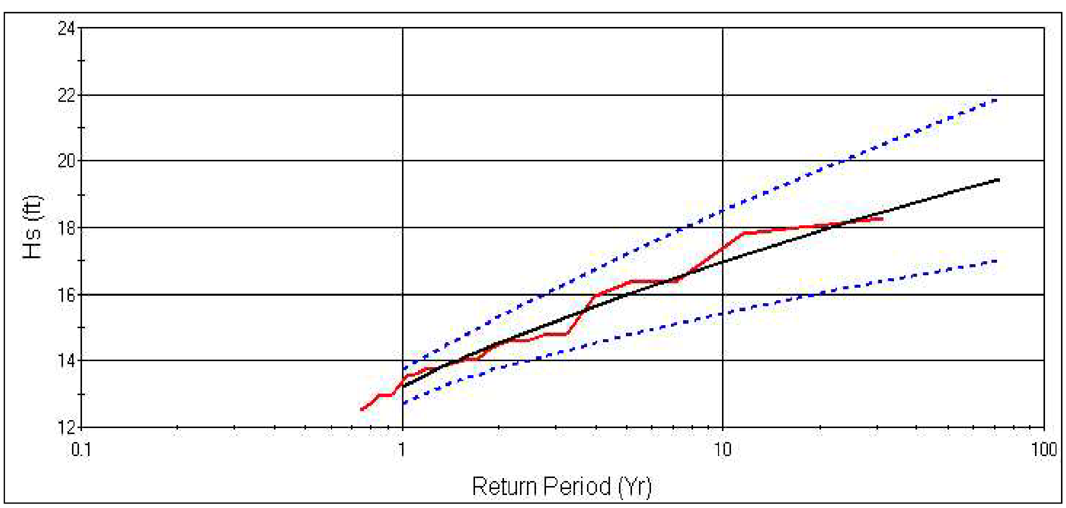

Figure 10. Extreme wave height analysis of data from WIS station 60.

The Weibull distributions for both WIS stations 58 and 60 indicate that the 50-year return period wave at the 66-ft depth contour is approximately the same at both of these stations, and equal to 19.4 ft and 19.0 ft at WIS stations 58 and 60, respectively.

Wave data from Buoy 42019 which is maintained by the National Data Buoy Center (NDBC) were analyzed. The wave rose plotted in Figure 11 was generated from five years of continuous data obtained from the buoy during the interval from 1995-2000. The average significant wave was 7.0 ft and the mean wave direction was 115 degrees. The majority of the waves approached the coast from the south-east direction.

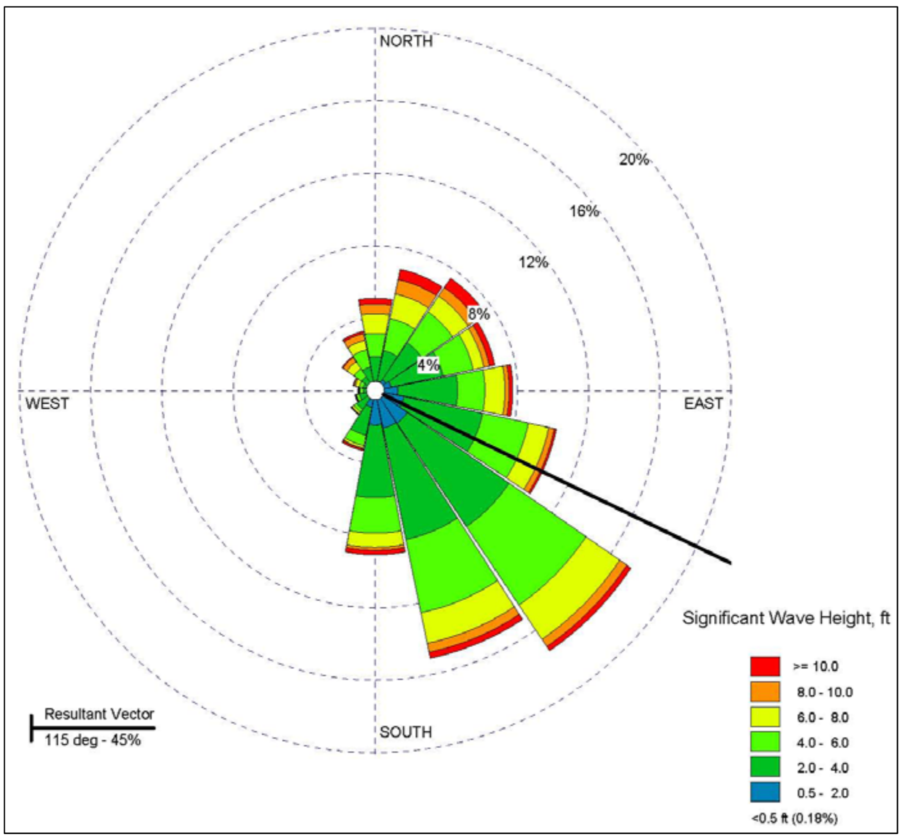

Figure 11. Wave rose for NDBC buoy 42019.

2.4 Relative sea level rise

The recent historic rate of local relative sea level rise (RSLR) was obtained from the nearest NOAA tide stations. These are at Freeport, TX (data analyzed from 1954 – 2006), and Rockport, TX (data analyzed from 1948 – 2006). RSLR observed at Freeport is equal to 4.35 mm/yr (0.014 ft/yr) with a 95 percent confidence interval of 1.12 mm /yr (0.004 ft/yr). RSLR

observed at Rockport is equal to 5.16 mm/yr (0.017 ft/yr) with a 95 percent confidence interval of 0.67 mm/yr (0.002 ft/yr). The average of these two observed rates is applied to estimate RSLR in the study area; 4.76 mm/yr (0.0156 ft/yr).

If we assume an historic eustatic rate equal to the globally averaged rate given for the modified National Research Center (NRC) curves (1.7 mm/yr (0.0056 ft/yr)), then the observed subsidence rate is 2.65-3.46 mm/yr, which averages to 3.05 mm/yr (0.01 ft/yr). Texas Department of Water Resources (Ratzlaff 1982) supports this observed rate, with an estimate of the land surface subsidence in this area of 0.15 m (0.5 feet) from 1918 to 1973, or approximately 2.72 mm/yr (0.009 ft/yr).

There is no scientific consensus on what the local subsidence rate should be for future projections. The relative influence of historic anthropogenic activities, such as oil extraction and groundwater withdrawal, are difficult to quantify. If these activities have contributed significantly to recent observations of subsidence, then the cessation of these activities may result in a rapid deceleration of subsidence rates, returning them to the long-term average rates. Several studies of basal peat layers have been conducted in the Texas and Louisiana coastal region to determine estimates of the long term average rates of subsidence. These rates are generally on the order to 0.05 mm/yr (0.00016 ft/yr) (Tornqvist et al.2006), significantly lower than the observed rates. Active surface faults have also been cited as the cause of local subsidence on Matagorda Peninsula (White et al. 2002). Therefore, if historic anthropogenic activities are largely responsible for the accelerated rates observed in the tide records, then rates may decelerate rapidly over the next several decades, adding potential conservatism to the subsidence calculation.

Table 7 gives the computed sea level rise based on USACE (2009) for the low (historic) rate, the intermediate (Modified NRC Curve I) rate, and the high (Modified NRC Curve III) rate. These rates are plotted in Figure 12. Computed sea level rise is based on a 50-year project life, and gives the predicted change for the years 2011-2061. The rates are calculated assuming that the historic average rate of subsidence for the two sites would continue for the next 50 years. Average values for beach slope, berm height, and depth of closure were applied to calculate shoreline change rate due to relative sea level rise using the Bruun rule (Bruun 1962).

Table 7. Projected future relative sea level rise (2011-2061).

	Low (historic)	Intermediate (modified NRC Curve I)	High (modified NRC Curve III)
Relative Sea Level Rise, ft	0.8	1.2	2.4
Shoreline Change, ft/year	-1.4	-2.1	-4.2

[1] Shoreline change due to RSLR is based on the Bruun rule.

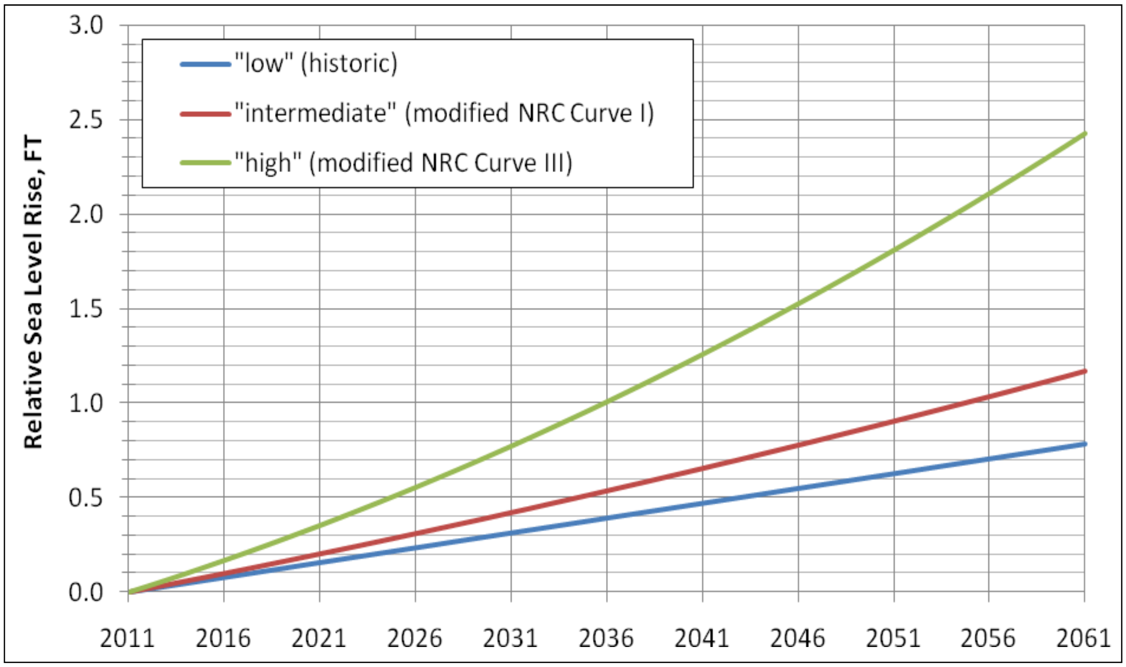

Figure 12. Projected relative sea level rise for 2011-2061.

2.5 Tropical storms

Tropical cyclones cause episodic beach erosion and are capable of eroding hundreds of feet of shoreline in just a few days. A total of 45 tropical cyclones have passed within 75 miles of Sargent Beach, TX[1] from 1886 to 2011. An additional 12 storms occurred within the period from 1851 to 1886, but these storms have limited information about track and category, so they were not included in the storm set.

Figure 13 plots the number of storms with tropical storm force or greater wind speeds per year. There are periods that did not have storms and seven years where multiple storms occurred in the same year. All categories of storms have made landfall within the study area. A majority of the storms

[1] Data downloaded from NOAA Coastal Services Center, 9/15/2011. www.csc.noaa.gov.

made landfall with tropical storm force winds (20). Category 1 is the next most frequent storm intensity (15). There was one storm of Category 2 intensity (2008- Ike), two of Category 3, six of Category 4, and one of Category 5.

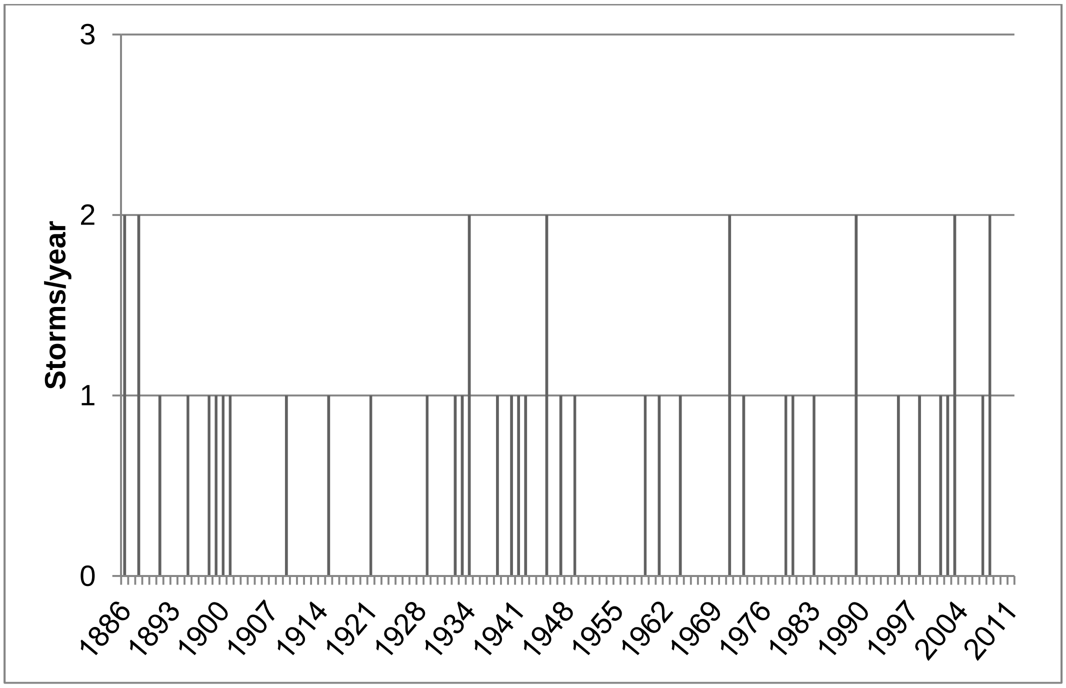

Figure 13. Number of tropical cyclones making landfall within 75 miles of Sargent Beach.

2.6 Shoreline change

Shoreline change rates were analyzed using a Geographic Information System (GIS) to interpret the historical shoreline positions available from the Texas Bureau of Economic Geology (BEG 2011) and aerial imagery flown during July 2011. The BEG digitizes the historical shoreline from aerial imagery as the boundary between the wet and dry beach, which is visually interpreted as the line of tonal color contrast from dark (wet beach) to light (dry beach) (Gibeaut et al. 2000). Airborne Lidar surveys were used to calculate the 2000 shoreline from the transformed digital elevation model (DEM) that is referenced to sea level (Gibeaut et al. 2000). The 1-m contour was extracted from the DEM and is comparable to the wet/dry line of the historical shorelines (Gibeaut et al. 2000). The GIS extension, Digital Shoreline Analysis System (DSAS), developed by the United States Geological Survey (USGS) (Thieler et al. 2009) was used to calculate the rate of shoreline change every 300 feet alongshore. Calculated rates of long term shoreline change were validated through comparison to rates previously published by BEG (2011).

The incremental shoreline change rates for the periods between 1850s to 1930s, 1930s to 1965, and 1965 to 1974 are plotted in Figure 14 for the 75 miles from Freeport to the MSC. The 1850s to 1930s period had milder shoreline change for the majority of the study area, except near the Freeport entrance where there was significant advance of the shoreline. This advance is attributed to impoundment of sediment at the west jetty. The 1930s to 1965 period experienced shoreline advance directly east of the Brazos River with erosion directly west. The period from 1965 to 1974 experienced erosion west of the Freeport entrance as the historic river delta migrated westward. Accretion also occurs to the east of the MCR and at mile 68 (Greens Bayou) which is an area of washover during storms and closes during periods of tropical quiescence (USACE 1992). Additionally, impoundment of sediment to the east of the MSC caused by the jetties has resulted in accretion of the shoreline for this time period. The data show that the rate of recession near Sargent Beach increases in each consecutive time period.

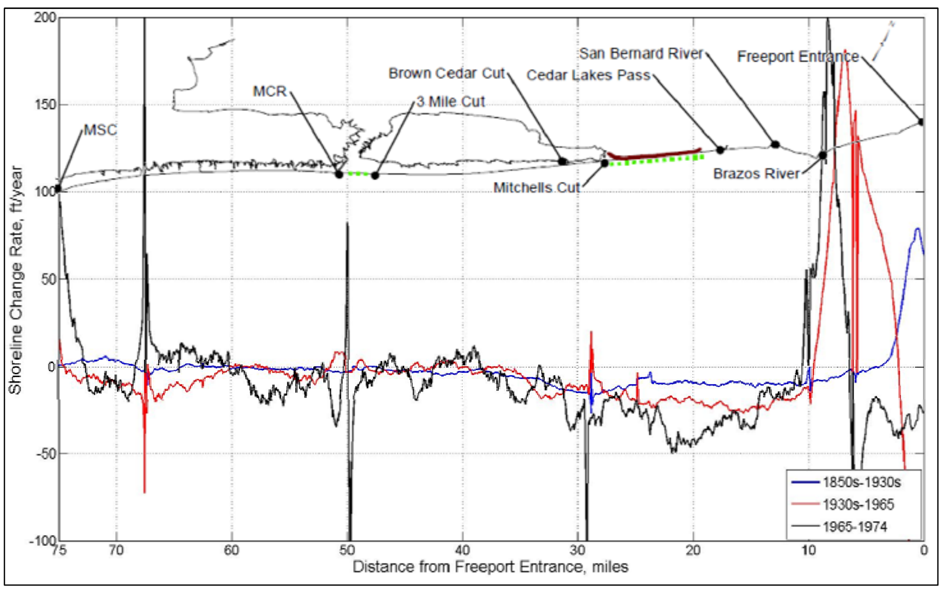

Figure 14. Historical shoreline change from Freeport to the MSC.

The shoreline change rate for an interval of 26 years from 1974 to 2000 based on the Texas BEG shoreline data is shown in Figure 15. Additionally, the incremental shoreline change rates for the period from 1974 to 1995 and 1995 to 2000 are shown. The areas that experienced the most shoreline advance from 1974 to 1995 occurred to the east of the Brazos River mouth. This advance, which was seen in the previous historical shoreline change rates, is attributed to the seaward migration of the Brazos River delta. The greatest erosion from 1974 to 2000 occurred in the vicinity of the Sargent

Beach revetment (approximately 26 miles west of the Freeport entrance). The shoreline advanced for the 1974 to 1995 and 1995 to 2000 time periods east of the MSC. The general trend of the shoreline change rates from 1974 to 2000 is erosional except at the Brazos River Mouth and in areas near inlets or cuts.

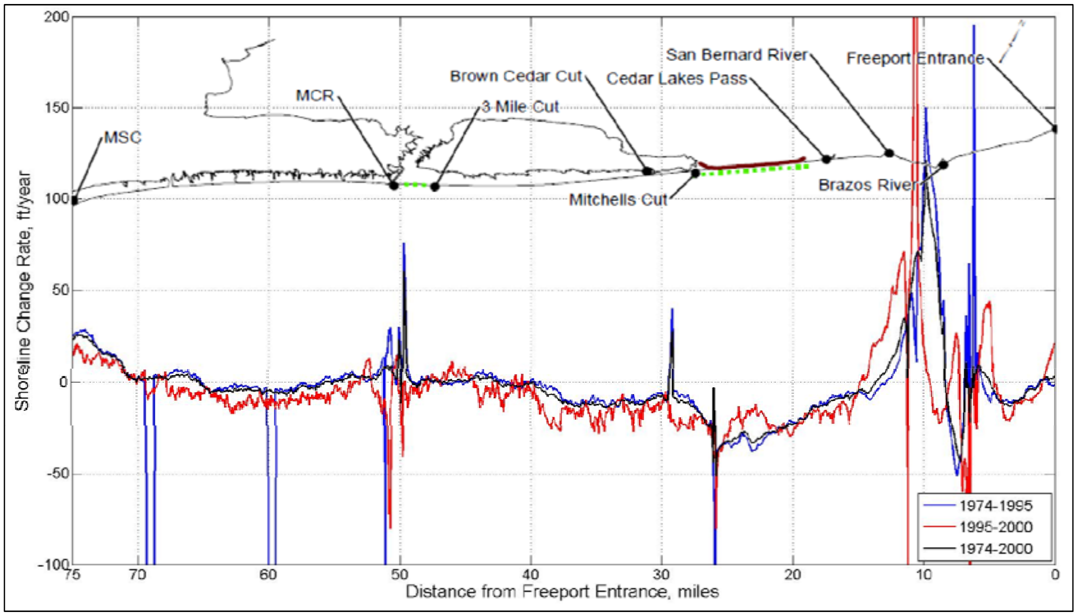

Figure 15. Modern shoreline change from Freeport to the MSC.

A more focused study of the shoreline change rate for the 35 miles east of the MCR to the San Bernard River is plotted in Figures 16 and 17 for the historical and recent time periods, respectively. The dashed vertical lines indicate the area of the revetment, which was built in 1998 to prevent breaching from the Gulf to the GIWW.

The 1965 to 1974 time period experienced the most shoreline erosion near the location of the revetment and approximately 16 miles west of the San Bernard River (SBR). Erosion at the 16-mile location is related to morphology of Brown-Cedar Cut, an historic ephemeral inlet to East Matagorda Bay.

Shoreline change rates for the recent time period (1974-2011) for the 35 miles east of the MCR to the SBR are plotted in Figure 17. The long-term shoreline recession rate (1974-2011) near the revetment continues to be much greater than at other locations. Shoreline advance is observed at Cedar Lakes Pass to the Brazos River. The rates between 1995 and 2000 and between 2000 and 2011 provide the short-term shoreline change rates for the area.

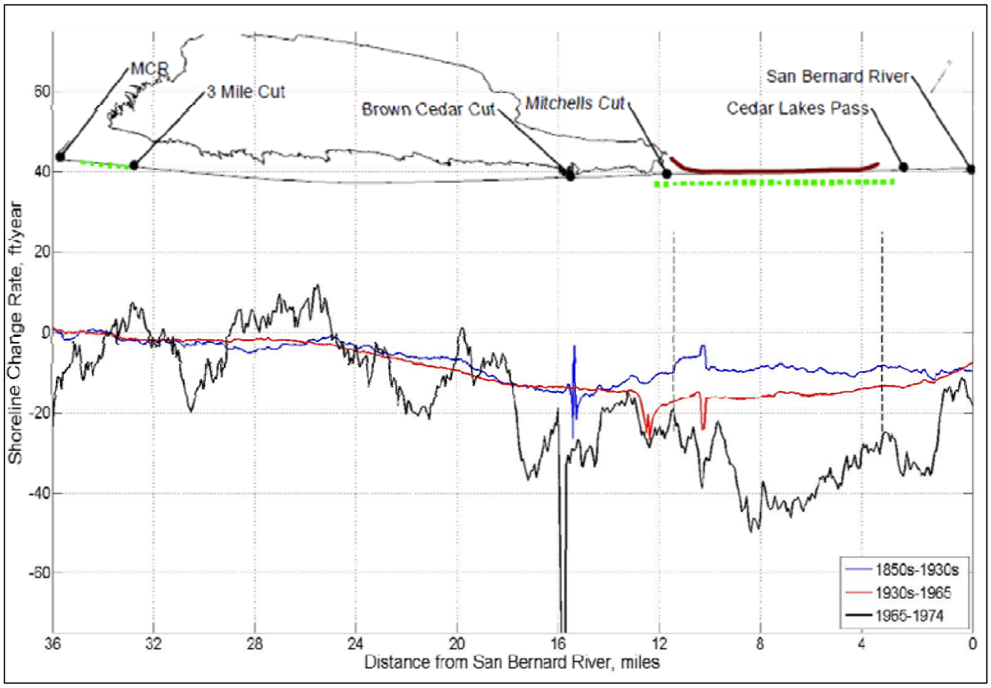

Figure 16. Historical shoreline change from SBR to MCR.

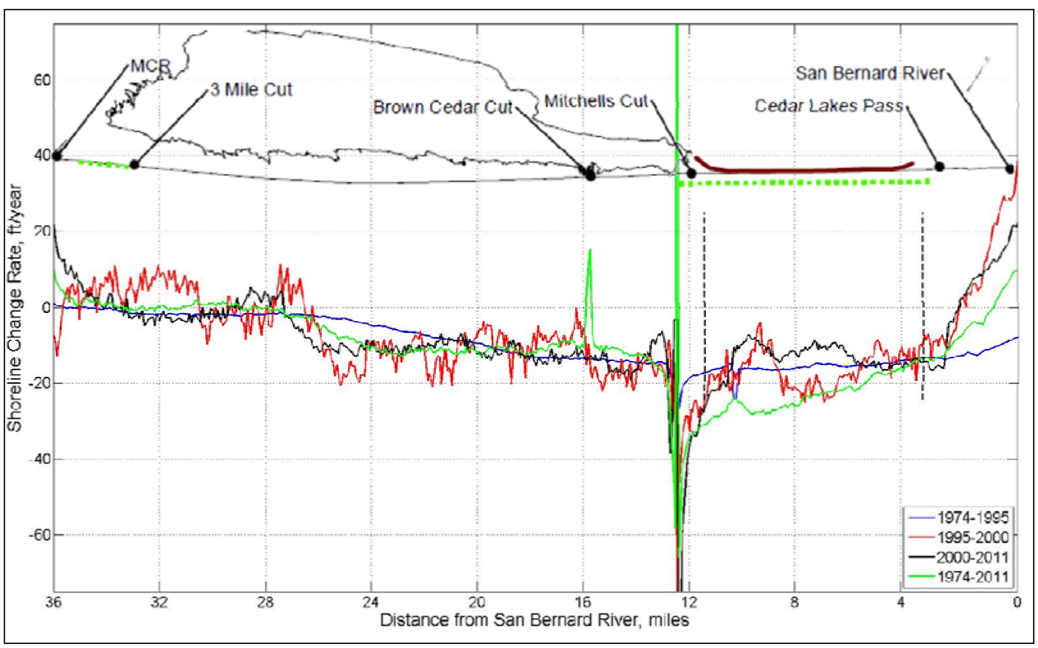

Figure 17. Recent and average shoreline change from SBR to MCR.

2.7 Regional geology

This coastal region is characterized as a storm dominated system where the primary longshore sediment transport is driven by storm generated waves and currents (Snedden et al. 1988; Davis and Hayes, 1984). The net longshore sediment transport direction is to the southwest. The primary

sediment source to the beach system has been the Colorado-Brazos River delta, which includes the Brazos River, Oyster and Caney Creek, and the San Bernard River (Weiss and Wilkinson, 1988). Previous authors have suggested that construction of flood control structures built along the rivers, as well as reduced discharge and sediment yield due to changes in the climate, have significantly reduced the amount of sediment that can enter the system, starving downdrift shorelines (Morton and Nummedal, 1982; Stauble, et al. 1994).

Sargent Beach is predominately comprised of river floodplain muds and marsh with a thin layer of shelly gravels and fine grain sand (Stauble et al. 1994), in contrast to predominantly sandy barrier islands more typical of the Texas coast. Sediment characteristics for the region are depicted in Figure 18. Stauble et al. (1994) offered insight into the mechanisms of erosion for this area. During the early Holocene period, a sandy barrier was seaward of the present Sargent Beach shoreline. The sandy barrier eroded during the late Holocene period sea level rise leaving the deltaic marsh environment of the Sargent Beach area exposed to waves.

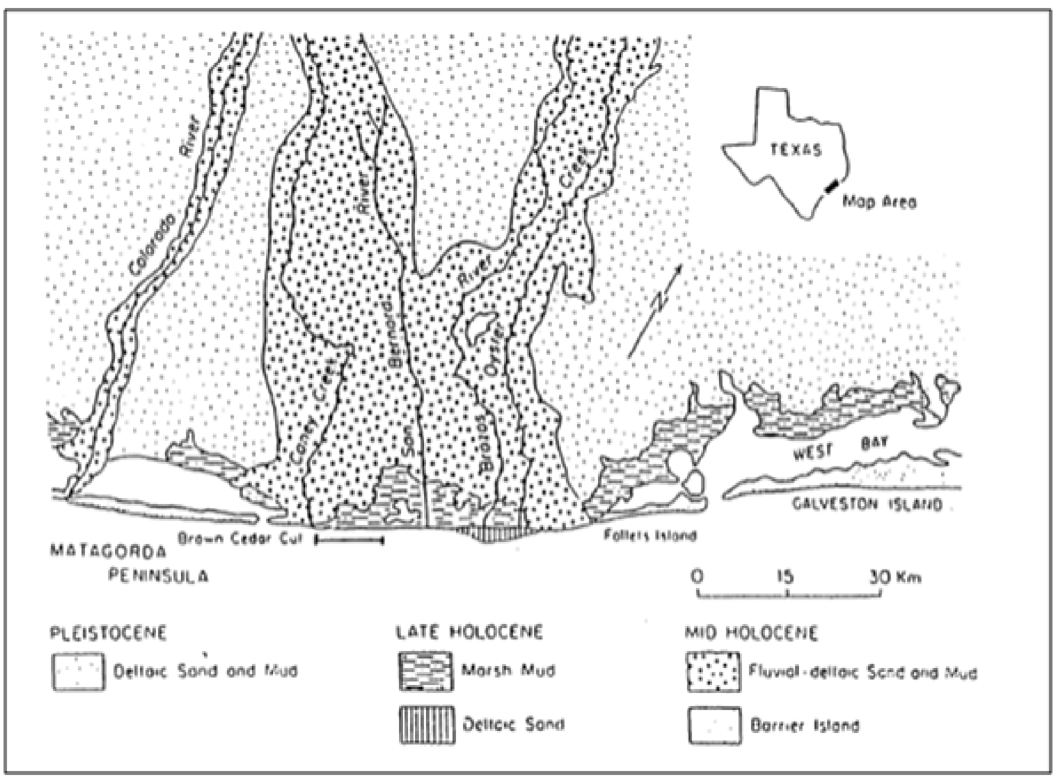

Figure 18. Regional map of sediment type (from Stauble et al. 1994).

The cohesive characteristics of the Sargent Beach sediment allow steeper profiles to form at the swash zone, as shown in Figure 19. The area is characterized by low bluffs which are separated by swales. The exposed predominantly cohesive sediments are limited to the northeast by Cedar Lakes Pass and to the southwest by Mitchells Cut, with a gradual transition to a thicker cover of sand at both ends. The Farm to Market (FM) 457 intersects Sargent Beach (Figure A-3). Figure 20 shows the beach near Cedar Lakes Pass. Figure 21 shows the beach on Matagorda Peninsula east of MCR where a thicker cover of sand with vegetated dunes can be observed.

2.8 Typical beach profile

Beach profile shape is a function of sediment size and other characteristics, geology, environmental forcing, and anthropogenic factors. The most recent beach survey data available at Sargent Beach are shown in Figure 22, collected by Baker and Lawson in May 2010. The survey consisted of 11 transects from the boat ramp at Sargent Beach to the east approximately one mile. A detailed review of historic trends in beach profiles is included in Stauble et al. (1994). Recent beach profiles continue to maintain the same basic shape observed from 1937 through 1990, although there is variation

Figure 19. Sargent Beach near FM 457, facing northeast (May 2011).

Figure 20. Cedar Lakes Pass, facing southwest (May 2011).

Figure 21. Matagorda Peninsula east of MCR, facing southwest (May 2011).

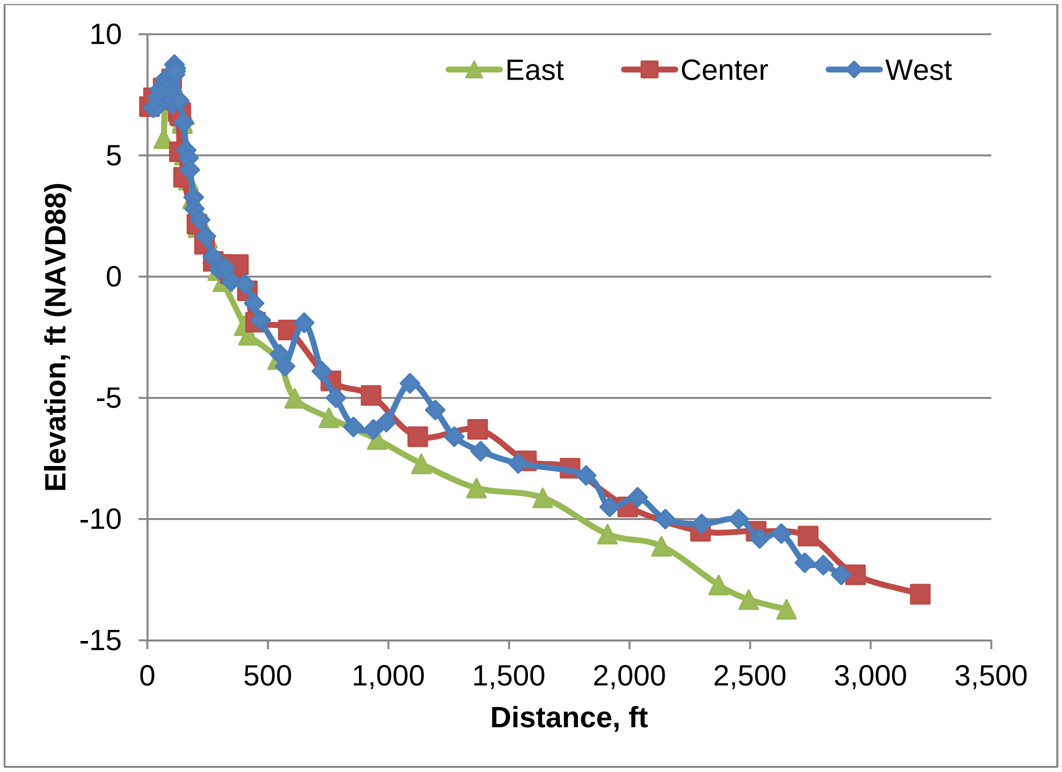

Figure 22. Recent beach surveys at Sargent Beach.

alongshore observed in the data. New beach surveys were measured at both the Sargent Beach and Matagorda Peninsula project sites in September 2011, which will be analyzed and applied in Phase 2. Pictures of beaches in the region are shown in Figures 19 – 21 above.

2.9 Mechanisms of erosion

Transport of non-cohesive sediments, sand, is reasonably well understood and modeled with existing technology. Supply of sand to the region is severely limited primarily as a result of natural geologic setting (limited sand sources), climate change (change in local precipitation and relative sea level rise), river diversion projects, construction of flood control structures (Fields et al. 1988), trapping at inlets, and construction of coastal structures and navigation projects. This limited supply of sand is causing recession of most of the Texas shoreline including this region.

Understanding the transport of cohesive sediments which compose Sargent Beach is less well understood and not easily modeled with state-of-the-art technology. Stauble et al. (1994) provided a detailed discussion of the mechanisms of erosion of the cohesive sediments at Sargent Beach, summarized below:

- Erosion of exposed clay bluffs on the beach face
    - Small tidal range, defined in Chapter 2, tends to focus wave action on the bluff toe
    - Breaking waves propel shell toward the bluff, abrading the bluff toe
    - Abrasion undercuts the bluff, causing large sections to fail

- Slope failure
    - Cyclical wave loading on the beach face weakens the sediments leading to block failure

- Swale acceleration
    - The bluffs, protrusions seaward, are separated by lower eroded areas, swales. Breaking waves rush into these swales, further increasing erosion in addition to the processes described above.

- Subaerial exposure
    - As the cohesive sediments remain exposed to the atmosphere, they begin to dry out. Cracks form as the sediment dries, reducing sediment strength.

- Lost in suspension
    - After the cohesive sediment blocks have fallen into the Gulf, the aggregate is broken up through wave action and abrasion.
    - Unlike sands, the finer cohesive particles do not settle within the active beach profile after they have been eroded. Eroded cohesive sediments are lost from the system, either transported beyond the depth of closure or into Matagorda Bay.

Although the general process of erosion of the cohesive beach is qualitatively described, technology to quantify transport accurately does not exist. Therefore, models adapted for non-cohesive transport will be applied to quantify these processes with the understanding that careful application of engineering judgment will be required when making decisions based on these numerical calculations. More detailed analysis of these processes in Phase 2 will help determine how to better apply these models when cohesive sediments are present.

3 Conceptual Sediment Budget

A conceptual sediment budget was developed for this region (Freeport to Matagorda Ship Channel (MSC)) to provide a framework within which to evaluate potential alternatives for reducing erosion at Sargent Beach and other Matagorda County beaches. A sediment budget is an accounting for sediments in a coastal system, represented graphically by a series of connected cells and fluxes. Cells are reaches of the study area that are either morphologically similar (e.g., an ebb tidal shoal), bracket similar data types and activities (e.g., navigation channel), or are separated by defined engineering actions (e.g., beach nourishment along a portion of region). Fluxes are the volume rate of exchange between, into, or out of cells. Sources and sinks are fluxes that provide and remove sediment from the cell, respectively. The difference between sources and sinks must equal the rate of change of volumes of sediment in each cell. A conceptual sediment budget is developed from available data to assist in guiding future investigation and data collection (Kana and Stevens, 1992). Following the development of a conceptual sediment budget, an operational budget uses the conceptual framework and refines values and resolution through additional data and/or numerical modeling. For this study, the operational budget, including uncertainty for values in the sediment budget, will be developed in Phase 2.

Equation 5.1 represents the sediment budget algebraically:

$$\Sigma\, Q_{sources} - \Sigma\, Q_{sinks} - \Delta V + \Sigma\, P - \Sigma\, R = Residual \tag{5.1}$$

where $\Sigma\, Q_{sources}$ and $\Sigma\, Q_{sinks}$ are the sum of the sources and sinks to each cell, respectively; ΔV is the net change in sediment volume for the cell; $\Sigma\, P$ and $\Sigma\, R$ represent the sum of Placements and Removals, respectively, for the cell; and $Residual$ is the degree to which each cell is balanced. For a balanced cell, $Residual$ = 0. A macro-budget solves Equation (5.1) for all cells. The $Residuals$ for a macro-budget and individual cells should equal zero for the entire budget to be balanced.

Data available from multiple sources were applied to develop this representative historical sediment budget, expressed in terms of annual rates. The Sediment Budget Analysis System (SBAS) was applied for

sediment budget calculations. New data to be collected and more detailed analyses during Phase 2 will be applied to refine this sediment budget.

3.1 Sediment budget cells

Cell locations were selected based on physical changes in processes, location of available data, limits of this study, and previous analyses. Sediment budget cells, along with some general notes on the calculations, are listed below from north to south with locations shown in Figure B-1 (Appendix B):

- Freeport Entrance Channel
  - Assumption: No sediment bypasses this inlet.
- Freeport to Brazos River
- Brazos River Mouth
- Brazos River to SBR
- San Bernard River Mouth
  - This cell is drawn to cover a section of beach wider than the existing SBR mouth to account for its movement over the period of analysis. Adjacent cells include the volume change associated with beach advance. SBAS transport rates are adjusted to account for this difference.
- SBR to Cedar Lakes Pass
- Cedar Lakes Pass
  - This pass is a sink; however, the volume trapped is unknown.
- West of Cedar Lakes
- Sargent: East of FM 457
  - Sargent Beach is separated into two cells to better represent project areas of concern.
- Sargent: West of FM 457
- Mitchells Cut
  - This pass is a sink; however, the volume trapped is unknown.
- West of Mitchells Cut
- East of MCR
- Mouth of Colorado River (MCR)

- MCR to MSC: North
    - o Dredging at MCR is placed on the north of this cell when possible. 70% is assumed to stay within the littoral system.

- MCR to MSC: South
- Matagorda Ship Channel
    - o Assumption: All sediment is trapped by the north jetty or channel.

3.2 Dredging

Dredging histories for federally maintained inlets within the region were evaluated to determine annual dredging rates. A database maintained by SWG includes most dredging contracts from as early as 1943 to 2004. Additional data collected after 2004 were obtained from personal communication with the respective Project Managers[1]. Table 8 lists the annual dredging rate and dredging interval, and the average time between dredging contracts. Mitchells Cut has not required dredging since construction in 1998.

Table 8. Annual dredging rate at inlets.

Cell	Average Annual Dredging, Cu yd/year	Dredging Interval, years	Period of Record
Freeport Entrance	1,047,000	1.3	1951 - 2006
San Bernard River Mouth	14,000	2.3	1943 - 2009
Mouth of Colorado River Entrance[1]	560,000	1.1	1990 - 2003
Matagorda Ship Channel Entrance	334,000	2.2	1971 - 2004

[1] Dredging data based primarily on SWG dredging database, augmented with more recent data.

3.3 Beach volume change

Change in beach volume for each cell was calculated based on the average long term shoreline change rate (BEG 2011). Recent beach profile data at Quintana (south of Freeport) and Sargent Beach were translated one foot landward; then the difference between the original and translated profile was calculated to determine a conversion factor to relate shoreline retreat/ advance to modern volume change. This resulted in a conversion factor of 0.9 cu yd/ft^2 for Freeport to Brazos Beach and 0.6 cu yd/ft^2 at Sargent

[1] Cliff Dominey, SWG, personal communication. July 2011.

Beach. Beach profile data were not readily available at other locations. A factor of 0.8 cu yd/ft^2 was applied at these locations for the preliminary analysis. Data were available to estimate the conversion factor at Sargent and Freeport. The typical factor of 0.8 cu yd/ft^2 was applied based on experience at other locations on the Texas coast. Surveys conducted in September 2011 will be analyzed to refine the conversion factor in Phase 2. Uncertainty and seasonal and annual variation in this conversion factor directly introduces uncertainty into the conceptual sediment budget. Table 9 lists the average annual volume change in each cell for the sediment budget.

Table 9. Annual volume change in each beach cell (ΔV) based on the long term historic shoreline change rate calculated by BEG (2011).

Cell	Average Shoreline Change Rate, ft/year	Length of Cell, ft	Conversion Factor, cu yd/ft^2	Annual Volume Change (ΔV), cu yd/year
Freeport to Brazos Beach	-15.5	30,500	0.9	-439,700
Brazos to SBR	62.5	15,000	0.8	750,000
SBR to Cedar Lakes	-12.0	21,500	0.8	-206,400
West of Cedar Lakes	-18.8	12,000	0.8	-180,500
Sargent: East of FM 457	-25.0	22,500	0.6	-337,500
Sargent: West of FM 457	-26.3	14,000	0.6	-220,900
West of Mitchells Cut	-11.5	59,000	0.8	-542,800
East of MCR	-1.1	56,500	0.8	-49,700
MCR to MSC: North	-2.9	85,500	0.8	-198,400
MCR to MSC: South	10.3	39,000	0.8	321,400

3.4 River sand supply

The Brazos River is the only significant source of fluvial sediment to the region (Seelig and Sorensen, 1973; Fields et al. 1988). Seelig and Sorensen (1973) report a value for the total supply from 1937 to 1973, listed in Table 10, as an annual rate. They go on to discuss factors limiting modern sediment supply, which may be further reduced since publication of that document. However, this estimate will be applied for this conceptual historical sediment budget.

For a brief period from 1934 – 1992, the Colorado River discharged directly to the Gulf of Mexico at the MCR. During this period, as much as

190,000 cu yd/year of sediment may have been input to the regional sediment budget (Kraus et al. 2008). A bypass channel is being constructed that may direct as much as 10 percent of the river discharge back into the Colorado River Navigation Channel (CRNC) to the MCR. No sediment input will be applied at MCR for this sediment budget.

Table 10. Sand supplied to the system by rivers.

Cell	Sand Supplied by River, cu yd/year
Brazos River Mouth	1,850,000
San Bernard River Mouth (SBR)	~0
Mouth of Colorado River (MCR)	Varies

3.5 Published longshore transport rates

Potential longshore sediment transport rates within the region have been calculated by others, as listed in Table 11. Rates reported for the same location by multiple sources or through multiple methods were averaged. Net transport is defined as the difference between transport in either direction and gross transport is the sum of transport in both directions.

Table 11. Potential transport rates reported for the region, listed by sediment budget cell.

Cell	Net Westward Transport, cu yd/year	Gross Transport, cu yd/year	Reference
Freeport to Brazos Beach	53,000	210,000	Fields 1988
Brazos to SBR	250,000	440,000	Kraus and Lin 2002
SBR to Cedar Lakes	250,000	440,000	Kraus and Lin 2002
West of Cedar Lakes[1]	-	-	
Sargent: East of FM 457	30,000	500,000	Seelig and Sorensen 1973
Sargent: West of FM 457	30,000	500,000	Seelig and Sorensen 1973
West of Mitchells Cut	50,000	-	Mason and Sorensen 1971
East of MCR	200,000	600,000	Kraus et al. 2008
MCR to MSC: North	200,000	600,000	Kraus et al. 2008
MCR to MSC: South	84,000	325,000	Kraus et al. 2006

[1] Indicates no readily available potential transport rate.

3.6 Cross-shore transport

Cross-shore transport is a sink for sediments in the region. Tropical storms are the primary forcing for cross-shore transport, although sediments may be transported beyond the typical depth of closure at inlets, or trapped in Cedar Lakes or Matagorda Bay. No rates for cross-shore sediment transport are included in the budget, although it is recognized that this is a large potential sink. As the budget and coastal models are better developed in Phase 2, a more detailed assessment of cross-shore transport will be included.

3.7 Relative sea level rise

As discussed in Chapter 2 (Table 7), RSLR accounts for 1.2 ft of shoreline retreat per year based on average beach characteristics, measured RSLR at two NOAA stations, and application of the Bruun rule (Bruun 1962). Since this conceptual budget represents the historical average, the influence of RSLR on volume change is captured in the measured shoreline change rates presented in the preceding Section. Applying the 1.2 ft/year shoreline retreat rate calculated using the Bruun rule, results in approximately 350,000 cu yd/year total erosion over the study area. The RSLR component will be represented in Phase 2 as a cross-shore loss to differentiate it from erosion induced by gradients in longshores and transport. Acceleration of RSLR would cause increased shoreline retreat and beach volume change if experienced in the future.

3.8 Summary and conclusions

The preceding data represent the preliminary sediment budget, processed in SBAS. Analysis of the data revealed a non-zero *Residual* in most cells; i.e., sediment fluxes do not match observed erosion or accretion, with consideration for engineering activities such as dredging and placement. It may be that the calculation factor for converting shoreline change rates to volumetric change rates is not accurate for all locations; factors for each reach will be refined in Phase 2. Table 12 lists the residual by cell. A positive residual indicates a volume of sediment that must be lost from the cell to match the observed volume change rate. Uncertainty and normal seasonal and annual variation in input to the sediment budget is also reported in the residual.

Table 12. Preliminary sediment budget cell residuals.

Cell	*Residual*, cu yd/year
Freeport to Brazos Beach	386,700
Brazos to SBR	-765,000
SBR to Cedar Lakes	430,400
West of Cedar Lakes	190,500
Sargent: East of FM 457	337,500
Sargent: West of FM 457	200,900
West of Mitchells Cut	392,800
East of MCR	49,700
MCR to MSC: North	390,400
MCR to MSC: South	-205,400
Macro-Budget	2,620,500

[1] Positive values indicate that the budget does not fully account for all measured losses.

One likely source of uncertainty is the broad assumption that average shoreline change, both in space and time, accurately represents beach volume change. The conversion factors applied were also averaged and based on very little data. Refinement to the conversion factors in Phase 2 will help reduce uncertainty, but not eliminate it. To help ascertain the influence of uncertainty in volume change on uncertainty in the residual, various values of the conversion factor were tested. The results show that, with reasonable variation in the conversion factor, the residual could vary by as much as 75 percent in the vicinity of Sargent Beach and more near MSC. The atypical beach sediments at Sargent Beach further complicate selection of an accurate conversion factor.

The macro-budget was used as a check to help verify sediment budget results over a large scale. The macro-budget extended from Freeport *to* Brazos Beach to *MSC*, excluding Freeport and Matagorda Ship Channels. Only residual for beach cells is shown in Table 12. The *Residual* for the macro-budget equals the sum of the *Residual* for all cells in the budget, excluding Freeport and Matagorda Ship Channels, verifying accurate accounting of sediment within the conceptual budget.

Evaluation of the magnitude of the *Residual* helps to enable the refinement of potential transport rates in the region and helps to identify sources and sinks that will be further evaluated in Phase 2. If we assume that all volumetric change calculations are accurate, we can infer some potential

reasons for these *Residuals*. Cell *Residuals* show that substantially more sediment accumulates between the Brazos and San Bernard Rivers as compared to published values of longshore transport. Deposition of Brazos River sands and redistribution of the inlet shoals is the source of this additional sediment (Fields et al. 1988); the additional transport capacity needed to deliver the sediment may be attributed to the increase in relative shoreline orientation as the river mouth has prograded.

The *MCR to MSC: North* cell has more sediment entering than shoreline change accounts for and the *MCR to MSC: South* cell has more leaving; therefore, it is likely that net transport is greater to the west here than previously estimated, accounting for the difference. Since this reach of the region is relatively far away from the focus area of this study, it does not need examination in more detail in Phase 2.

There is consistently more erosion between *SBR to Cedar Lakes* to *West of Mitchells Cut* than is indicated by the conceptual budget. A total of 1,552,100 cu yd/year is not yet accounted for in the budget for this reach (similar to results published in Seelig and Sorenson 1973). The following processes may account for the sediment loss:

- Erosion of fine grained sediment: The cohesive sediments found on Sargent Beach are not likely to be deposited on adjacent beaches after erosion. Measurements at Trinity Island on the LA Gulf of Mexico coast indicate that these sediments may erode at a rate as much as five times faster than a sandy beach in the same location[1].
- Cross-shore transport during storms: Large waves and high surge during storms act to transport sediment offshore beyond the depth of closure and onshore through overwash. This process causes significant erosion and is not included in the conceptual sediment budget. Seelig and Sorenson (1973) theorized that this was the primary mechanism responsible for sediment losses in the region not accounted for in their sediment budget. Coastal Tech (2010) cites this as a primary transport mechanism at Sargent Beach.
- Trapping at inlets: Sediment is trapped in ebb shoals and bays at inlets. In addition to Mitchells Cut, many ephemeral inlets form during storms in this region. Seelig and Sorenson (1973) attributed about 40,000 cu yd/year to sediment trapped at Brown Cedar Cut.

[1] Analysis by Dr. Julie Rosati (USACE) of data collected by John Dingler (USGS).

This conceptual sediment budget represents the historical average conditions within the region. The main conclusions applied for project design are summarized below:

- There is insufficient sand sized sediment available to maintain shoreline position, leading to overall shoreline retreat throughout the region.
- Sediment supplied by the Brazos River is deposited in a relatively small region surrounding the river mouth because sufficient potential transport does not exist to carry it far away. Future sediment supply at the Brazos is unknown.
- The sediment budget highlights processes at Sargent Beach responsible for the extreme erosion in this area, which are poorly understood. As stated previously, the cause is likely a combination of cross-shore transport, fine grained sediments, and trapping at inlets.
- The sediment budget west of Mitchells Cut is reasonably well balanced. Uncertainty in volume change and transport explains observed residual.

3.9 Recommendations to refine sediment budget in Phase 2

The sediment budget will be refined during Phase 2 to include the following:

- Investigate recent rates of sediment supply from the Brazos River through review of existing data, interviews with experts, and analyzing numerical model results
- Calculate variation in longshore transport at Brazos River to balance sediment budget and to better refine potential impacts the diversion project has had on shoreline change west of the Brazos
- Improve calculation of sediment trapped at inlets by bathymetric and photographic change analysis
- Analyze new survey data to refine volume change in sediment budget cells
- Investigate temporal variability of sediment budget through examination of historical data sets
- Improve understanding of storm induced transport and volume change through cross-shore numerical modeling
- Include uncertainty in volumetric change rates and sand fluxes within the sediment budget
- Acquire sediment samples across the shore to the depth of closure if possible

- Based on the available data and the degree to which each sediment budget cell represents the assumptions inherent in this analysis, define confidence for each cell as "good," "medium," and "poor."

The next chapter discusses a numerical model that will help address future with and without project conditions. The conceptual sediment budget developed will be applied to help validate the numerical model. Improvements to the sediment budget during Phase 2 will help further validate the numerical models developed in Phase 2.

4 Coastal Process Model Development: GenCade

This chapter describes the set up and calibration of the GenCade model (Frey et al. 2012). GenCade was applied to the study area to model longshore transport, inlet volume evolution, and shoreline change. The calibrated model presented in this chapter will be applied to help quantify impacts and improvements resulting from proposed solutions to reduce erosion.

4.1 Numerical model approach and conventions

4.1.1 Description

GenCade is a one-line model of shoreline change with the added capability of inlet volume evolution. Coupling the inlet model with the one-line model makes it possible to apply GenCade over larger spatial scales without the need for multiple grids. It also adds functionality to relate inlet volume deficits to shoreline change. GenCade is capable of simulating shoreline response to beach nourishment, inlet dredging, construction of groins, jetties, and breakwaters, as well as changes in the wave climate. GenCade is still under development; *version 1_1mbeta* was applied for this study.

Software limitations

GenCade is constrained by the standard assumptions upon which one-line models are based (Frey et al. 2012):

- The beach profile shape remains constant.
- The shoreward and seaward depth limits of the profile, the “berm height” and “depth of closure,” respectively, are constant.
- Sand is transported alongshore by the action of breaking waves and longshore currents.
- The detailed structure of the nearshore circulation is ignored.
- There is a long-term trend in shoreline evolution.

The complex processes at Sargent Beach related to the presence of cohesive sediments clearly stretch the assumptions stated above; however, no better model exists to evaluate the long term function of proposed alternatives.

Therefore, it is important to consider the model results qualitatively and to apply engineering judgment in their application to design.

4.1.2 Units, coordinate system, datum

Standard International (SI) units are applied in all model runs. Units are converted to the U.S. Customary System for display in this report. The horizontal coordinate system is Universal Transverse Mercator (UTM), Zone 14. The horizontal datum is NAD83 and the vertical datum is NAVD88.

4.1.3 Direction convention

The GenCade grid is aligned so that the water is on the left hand side of the grid when facing the positive direction. Transport is negative to the left when facing the water and positive to the right. Waves may be imported in any sign convention; the model automatically converts to grid normal.

4.2 Model domain

The GenCade model domain (Figure 23) extends from SBR to MSC. It contains a total of 655 grid cells with variable size from 130 to 490 ft (40 to 150 m) with smaller cells near structures and inlets. Total length of the grid is approximately 54.75 miles (94.5 km). The GenCade model origin is located less than 1 mile southwest of the SBR mouth.

4.3 Model forcing

Data from WIS hindcast stations 73053, 73055, 73058, and 73060 were applied. Location of the wave gages relative to the GenCade grid is shown in Figure 23 with red partially filled circles (note that true location of the gages is offshore at their respective depths). The time period from 1995 to 2000 was used to represent typical conditions for model development and to compare to the calibration data available. Different and longer time periods will be analyzed during Phase 2.

4.4 Initial shoreline position

The 1995 shoreline position (BEG 2011) was smoothed and applied as the initial shoreline position for calibration. A composite shoreline was applied to represent existing conditions based on the most recent July 2011 aerials in the project area and the 2000 shoreline position southwest of MCR beyond the range of the recent data collection effort.

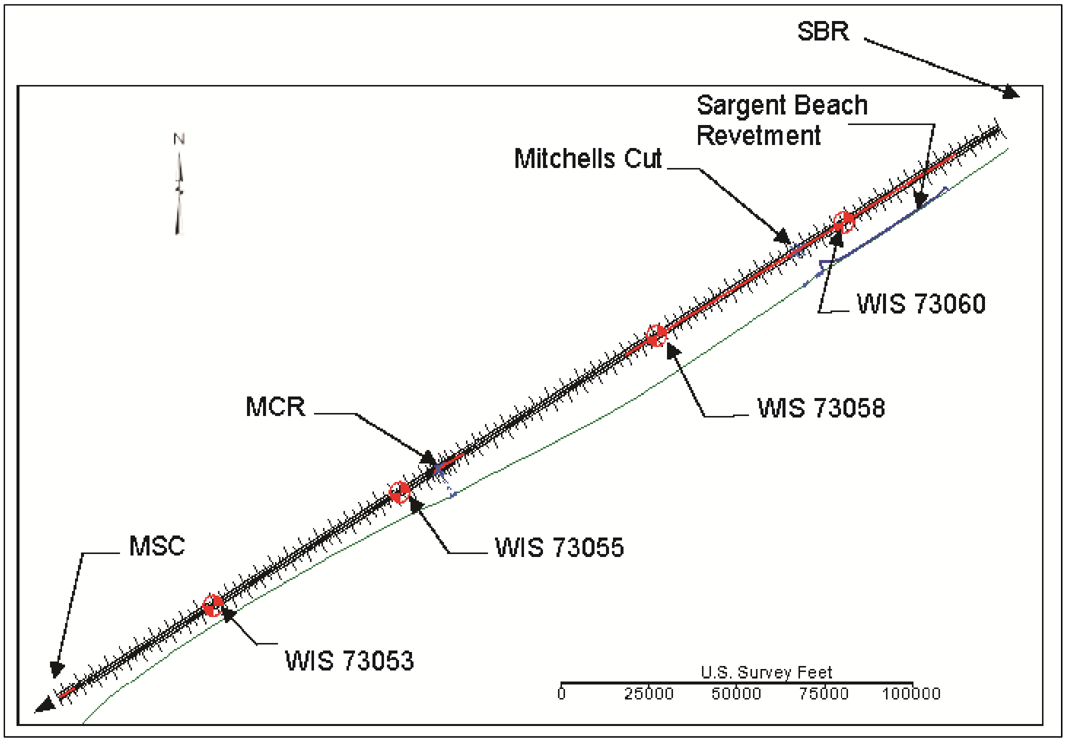

Figure 23. GenCade model domain.

4.5 Inlet shoal volumes

GenCade applies a limited version of the Inlet Reservoir Model (Kraus 2000) to calculate inlet evolution impacts to adjacent shorelines. The model requires an initial volume and equilibrium volume for calculation and allows user specified reductions of shoal volumes in time (i.e. to represent dredging). The shoals trap sediment at rates varying with their volume at that time step until the volumes equal the equilibrium volume, at which point complete bypassing will occur.

Equilibrium volumes for the inlet shoals were approximated based on aerial photographs. The area of the shoal was approximated in a GIS based on inlet size, then an average thickness of three feet was assumed. For comparison, relationships published in Walton and Adams (1976) estimate ebb shoal volume at Mitchells Cut would be over 20,000,000 cu yd based on a tidal prism of 38,000,000 cu yd. Volumes were iteratively adjusted along with the initial volume to achieve model calibration. Data collected in September 2011 will allow calculation of the shoal volumes at Mitchells Cut during Phase 2. Planned condition surveys at MCR may allow calculation of shoal volumes. Table 13 lists inlet shoal volumes applied.

Table 13. Inlet shoal volumes, cu yd.

	Mitchells Cut		MCR	
	Initial	Equilibrium	Initial	Equilibrium
Ebb	457,800	915,600	327,000	327,000
Flood	1,308,000	2,615,900	700	700
Left Bypass	13,100	26,200	26,200	26,200
Left Attachment	13,100	26,200	26,200	26,200
Right Bypass	13,100	26,200	26,200	26,200
Right Attachment	13,100	26,200	26,200	26,200

4.6 Sediment bypassing

Dredging operations and sediment lost at MSC and MCR were included in the model setup through addition of bypassing values. The bypassing function allows sediment to be removed (negative value) or added (positive value) over a preset number of cells. In this case, sediment was removed from the updrift side of MCR and added to the downdrift side. Sediment was removed from the updrift side of MSC, but was not added since the placement area is outside the model domain. The rates applied were determined through examination of dredging records and as part of the calibration process. Table 14 lists the bypassing rates applied.

Table 14. Sediment bypassing operations.

Location	Begin Date	End Date	Start Cell	End Cell	Bypass Rate (cu yd/year)
East of MCR	1-Jan-95	30-Dec-99	360	389	-515,600
West of MCR	1-Jan-95	30-Dec-99	393	400	515,600
East of MSC	1-Jan-95	30-Dec-99	645	654	-916,600

4.7 Boundary conditions

Measured shoreline change at both the left and right boundaries provided boundary conditions. Boundary conditions are shown in Table 15 below. Measured historical change was applied to evaluate alternatives.

4.8 Summary of model parameters

In addition to the previously discussed parameters, the average berm height and depth of closure were specified based on typical beach profiles. A median grain size was specified based on cores and grab samples collected

Table 15. Summary of model input parameters.

Parameter	Value
Start Date	1/1/1995 0:00
End Date	12/30/1999 0:00
Time Step	0.5 hr
Recording Time Step	168 hr
Effective Grain Size, mm	0.2
Average Berm Height, ft	3.3
Average Depth of Closure, ft	19.7
Left Lateral Boundary Condition, moving (ft per 5 years of simulation period)	217
Right Lateral Boundary Condition, moving (ft per 5 years of simulation period)	131

by USACE in 1990 (location shown in Figures A-2 and A-3). Berm height is the elevation of the berm for a typical beach profile. Depth of closure refers to the elevation of the seaward limit of sediment transport for the time period of consideration. The length of this reach makes it likely that the spatially constant assumption for these parameters is not accurate; however present model limitations prevent varying these parameters spatially. Additional samples and surveys measured in September 2011 will help to refine these parameters. Table 15 summarizes the model input parameters.

4.9 Model calibration

GenCade must be calibrated with measured data to properly estimate transport rates and shoreline change. The calibration process is iterative, starting with varying parameters to match observed net and gross transport rates and finishing with fine tuning to better match observed shoreline change. In this application, numerous iterations of GenCade were evaluated by comparing calculated net and gross transport rates and shoreline change to available measurements or estimates. Table 16 lists the parameter values found to best represent the observed data through the calibration process. Goodness of fit was based on root mean square error between the calculated shoreline after five years from 1995 to 2000 and the observed 2000 shoreline position.

In Table 16, K1 and K2 are sand transport rate coefficients, and the values selected are similar to those selected at other locations on the Texas coast (King 2007). The Height and Angle Amplification Factors are set equal to 1, indicating no increase or reduction of the measured values. An angle offset

is applied to force net transport to the west. This factor is commonly applied at locations with coarse wave data or where there is very low net transport, like Sargent Beach. Without this factor, the model calculates low net transport to the east at Sargent Beach, contrary to common knowledge and observed processes. Finally, the number of cells in the offshore contour smoothing window specifies the length over which the shoreline is smoothed to develop a representative offshore contour for wave refraction calculations.

Table 16. Model parameters selected through calibration.

Parameter	Value
K1	0.27
K2	0.3
Height Amplification Factor	1
Angle Amplification Factor	1
Angle Offset	5.5°
Number of cells in offshore contour smoothing window	50

Figure 24 shows the initial shoreline position with key features labeled. Comparison between calculated net and gross longshore transport rates to those estimated by others are shown in Figures 25 and 26, respectively. Comparison between calculated and observed shoreline change rates are shown in Figure 27.

The model calculated net transport rates similar to those calculated by others; calculated gross transport rates are slightly lower than those reported in the literature. An angle offset factor was applied to achieve the desired net transport direction. This is a common practice when applying WIS hindcast waves, because the directional resolution in the wave model often results in minor uncertainty in direction but the incorrect average direction has a determining factor on the rate and magnitude of transport rates and the resulting shoreline change.

Shoreline change is calculated reasonably well near Sargent Beach and on Matagorda Peninsula between Mitchells Cut and MCR. West of MCR, GenCade calculates advance where shoreline recession was observed and greater advance than observed farther south near the MSC.

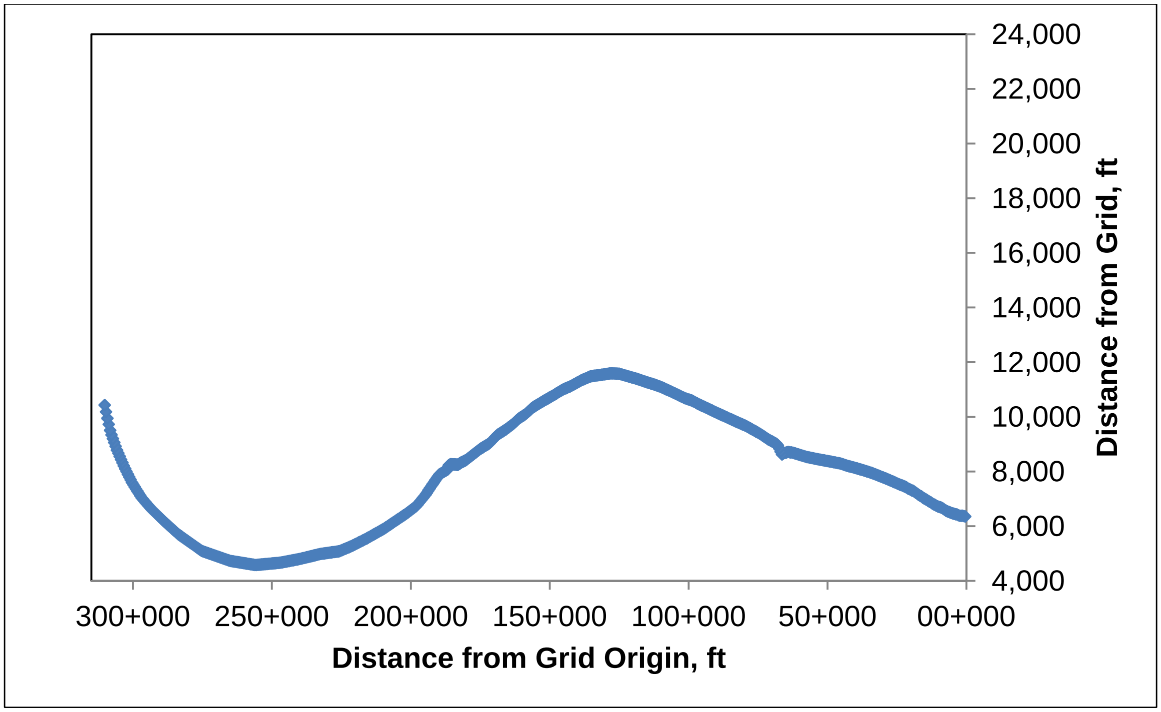

Figure 24. Initial GenCade shoreline position showing locations of key geographic features.

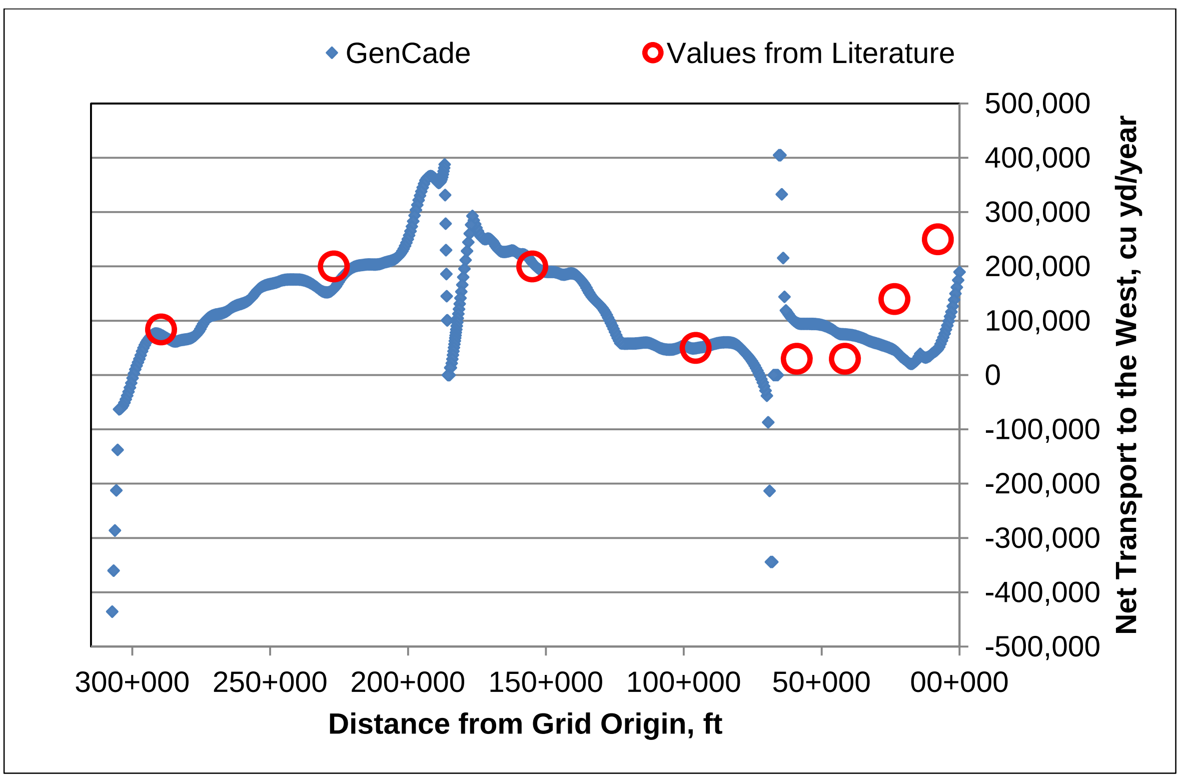

Figure 25. Net transport, model results versus published values for the calibration case.

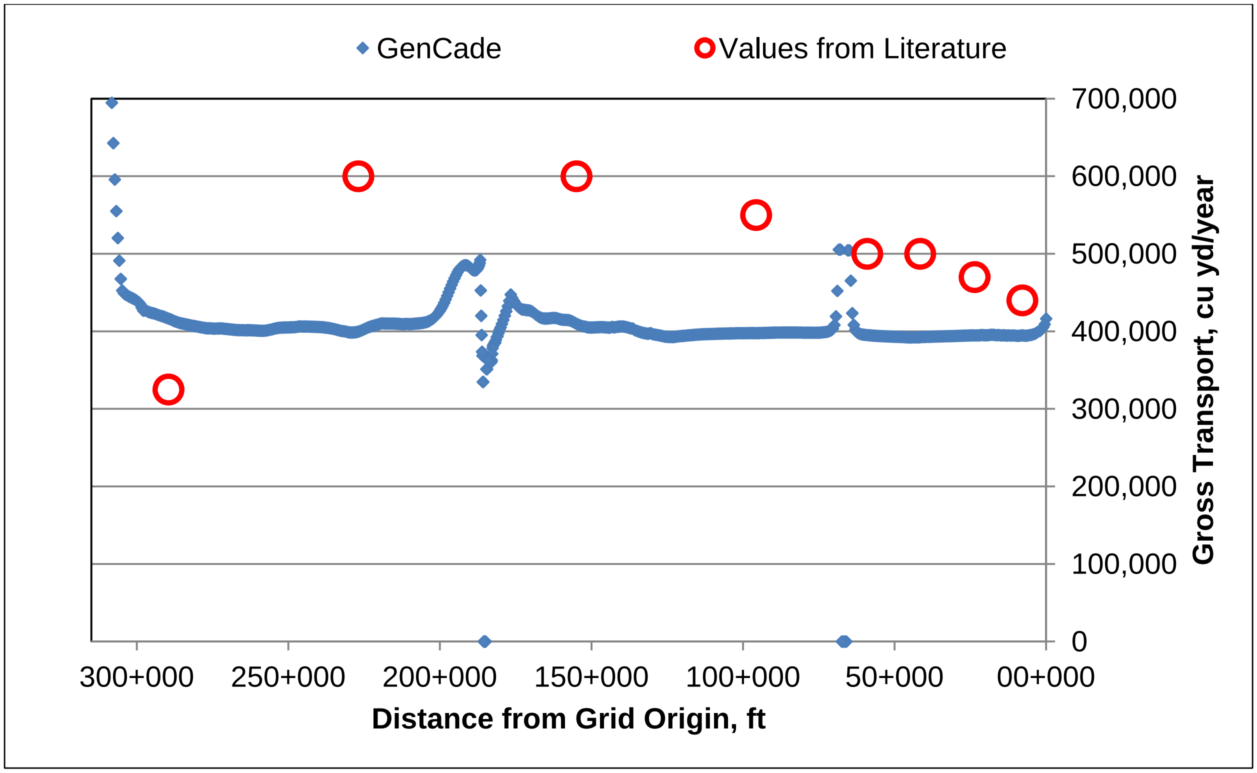

Figure 26. Gross transport, model results versus published values for the calibration case.

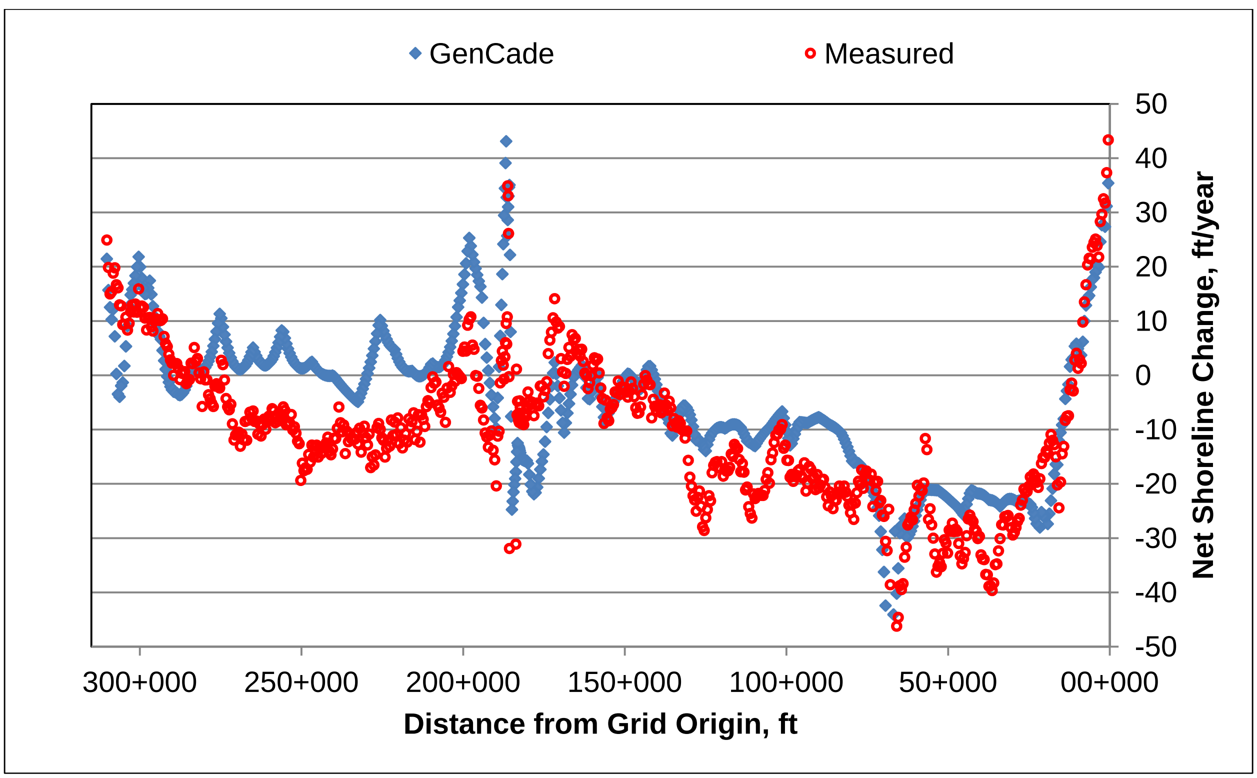

Figure 27. Shoreline change, model results versus published values for the calibration case.

Table 17 shows two goodness of fit statistics applied to evaluate the GenCade model; root mean square (RMS) error and Brier skill score (BSS). The BSS is a measure of how well the calculated position matches the actual position, a score of 1 is a perfect match, and less than 0.3 is considered very poor.

Table 17. Shoreline change modeling statistics.

Cell	Average Shoreline Change, ft/year		RMS Error, ft/year	Brier Skill Score
	Measured	Modeled		
SBR to Cedar Lakes	10.5	10.2	5.3	0.93
West of Cedar Lakes	-20.1	-23.7	7.3	0.88
Sargent: East of FM 457	-31.3	-23.0	9.1	0.92
Sargent: West of FM 457	-29.0	-25.3	7.9	0.93
West of Mitchells Cut	-19.7	-13.8	8.7	0.81
East of MCR	-4.5	-6.9	7.5	0.27
MCR to MSC: North	-8.0	4.8	13.9	-0.66
MCR to MSC: South	4.9	5.8	7.4	0.36

Both goodness of fit statistics in Table 17 show that the model performs well between SBR to east of the MCR, after calibration was complete. Initially, the GenCade model under calculated shoreline loss by over 1,000,000 cu yd/year between SBR and MCR. After exhaustive variation of model parameters, the only method to reproduce shoreline recession in the region was to extract an additional 1,314,000 cu yd/year (150 cu yd/hour) from the Sargent Beach and West of Mitchells Cut cells. Recall from the sediment budget discussion that 1,121,700 cu yd/year of sediment remains as residual loss in the budget in this region, a conclusion also supported by Seelig and Sorensen (1973).

The requirement to introduce volume loss into the model in this manner indicates that a vital process is not included in the model. It's likely that the missing process is a combination of cross-shore losses, loss of fine grained sediments, and trapping at the inlets as well as error typical with this class of model. These additional processes will be better refined during the Phase 2 investigation; however, the present model configuration will be applied for testing the preliminary alternatives. Since analysis of shoreline change at Sargent Beach includes so much uncertainty associated with the cohesive sediments, shoreline response may be different if sand were placed over the

cohesive sediments. Various alternatives to be evaluated in the next Chapter include beach nourishment. Therefore it is possible that the model will over calculate erosion rates for those alternatives (i.e., model calculations will be conservative).

5 Preliminary Analysis of Alternatives

Physical processes described in the preceding Chapters were considered to help develop different alternatives to reduce beach erosion in the two areas of concern. Each alternative represents a general design concept (i.e. nearshore breakwaters, groins, beach fill, etc.). The general concept was iteratively modified to find a solution that appears to provide the best protection. For clarity, only the final layout of the iterative process is shown for each general concept. This Chapter does not include detailed design information. Preliminary design will be conducted for select alternatives in Phase 2 of this project.

This Chapter is separated by location and further by alternative, ending in a comparison of the alternatives and recommendation for further analysis. Layouts for each alternative, excluding the No Action alternatives, are shown in Appendix C.

5.1 Sargent Beach

5.1.1 Alternative 0: No Action

The baseline alternative is to take no action. Since there is no planned modification, the existing conditions figures shown in Appendix A are representative and no additional layout figure is included in Appendix C.

Shoreline change

The GenCade model developed in Chapter 4 was applied to analyze shoreline change. The July 2011 shoreline was specified as the initial shoreline and the five year analysis period described in Chapter 5 was applied to calculate shoreline change. Figure 28 plots the net shoreline change after five years; negative values indicate erosion over the five year period and positive values indicate accretion. The model calculates that the shoreline will have reached the revetment within five years over more than half its length; from station 25+000 to 55+000 in Figure 28. Accretion calculated towards the west end of the revetment is an area not well represented in the model and these conditions will likely not occur in the future.

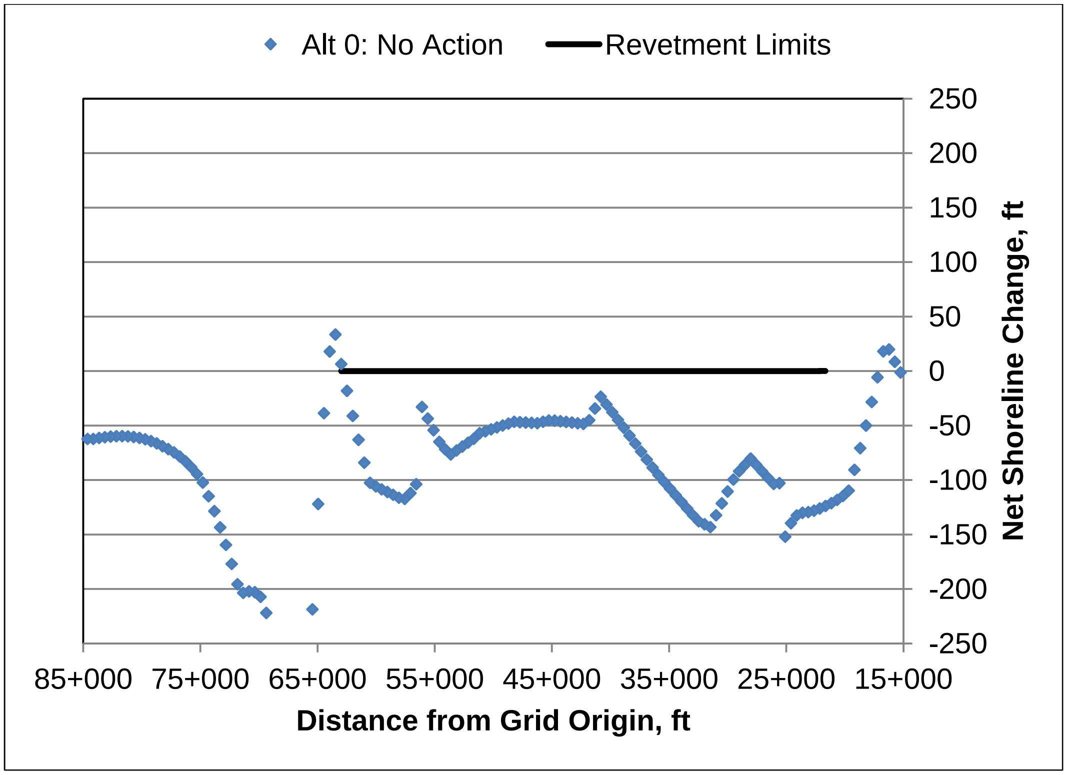

Figure 28. Sargent – Alt. 0: Net shoreline change after five years.

Discussion

If the erosional trend continues, this baseline scenario will result in exposure to a majority of the existing revetment within the next few years. This may cause increased erosion adjacent to the revetment since sediment being eroded from that beach will no longer be available to the adjacent beaches. Environmental impact, storm damage protection, regional implications, and cost for this scenario are documented in USACE (1993).

5.1.2 Alternative 1: Beach fill

Beach nourishment is the most direct method of combating beach erosion. Beach nourishment design documented in Stauble et al (1994) was applied for preliminary nourishment. The fill consists of approximately three million cu yd of sediment placed over 10 miles for a placement density of 57 cu yd/linear ft (lf). Stauble et al. (1994) estimated this would provide approximately 100 ft of added berm width and require renourishment every three years. Figure C-1 shows the layout of the beach fill design. This alternative is scalable; however, if a shorter length of beach is nourished, the fill should be expected to require more frequent renourishment. Coastal Tech (2010) presented preliminary design including beach nourishment on

Sargent Beach which documents potential sand sources, cost, performance, and design for a limited placement.

Shoreline change

Beach nourishment was added to the GenCade model previously described. Figure 29 plots net shoreline change after five years, compared to the No Action alternative. The results show that nourishment effectively offsets erosion and confirms that renourishment is required approximately every three years. No negative impacts are observed on adjacent shorelines. Because the 2011 shoreline is so near to the revetment, without continued renourishment, the shoreline still intersects the revetment at two locations within the five year period.

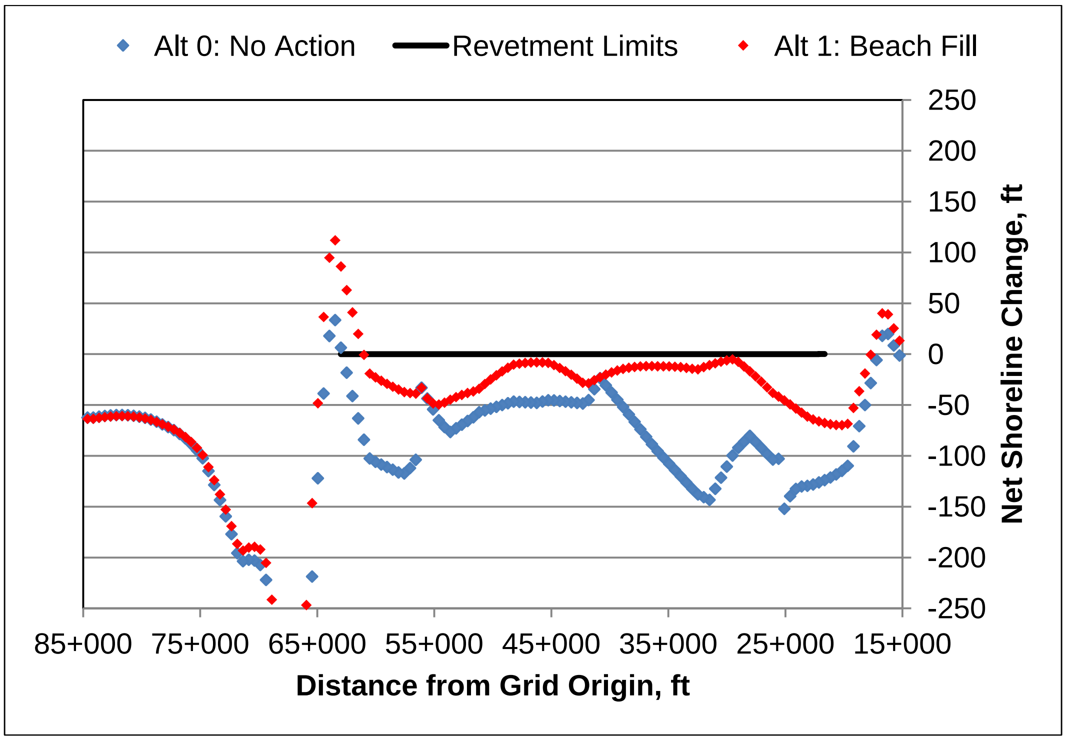

Figure 29. Sargent – Alt. 1: Net shoreline change after five years with three million cu yd of beach fill.

GenCade results are based on the continued assumption that about 1,314,000 cu yd/year (or 150 cu yd/hr) of erosion occurs in the Sargent Beach area as a result of processes not resolved in the model. Placing sand beach fill may reduce this erosion rate because the sand may erode slower than the cohesive sediments, increasing project longevity. Therefore, these results may be conservative.

Environmental considerations

Beach nourishment will provide additional beach width and provide a sandy beach as opposed to the existing cohesive material. These improvements will create more hospitable conditions for myriad species, which could include the threatened Piping Plover and endangered sea turtles, which frequent the beaches of the Texas coast (Davenport 2010). Impacts to the environment and the threatened and endangered species should be considered when planning for dredging of beach quality sand and placing the beach fill.

Primary impacts for this alternative are construction activities. To alleviate impacts to the endangered sea turtles, the dredging and beach fill placement activities would not occur during their nesting season (April 15-October 1). Precautionary steps can be implemented to reduce the impact to the threatened Piping Plover and the other species that inhabit the area. Placement of beach fill may cover organisms that inhabit the surf zone, but due to the resiliency of these creatures to the dynamic coastal environment, long-term impacts are not anticipated (Davenport 2010).

If beach fill sediment would be obtained from offshore borrow areas, dredging could result in adverse impacts to the environment. Typical dredging considerations can include increased turbidity and disruption to benthic habitat. Also, precautions should be used to reduce the number of sea turtles entrained during the dredging process.

Habitat protected

Beach habitat will be created for this area with the addition of sediment for the beach nourishment project. Beach nourishment provides storm damage protection to landward habitat.

Storm damage vulnerability

The benefit of beach nourishment is that it adds sacrificial sediment to the system that can be eroded during storm events thereby protecting upland infrastructure and critical habitat. Addition of sediment to the system provides added protection to adjacent beaches as well as the target beach.

Constructability

Identifying suitable and affordable sand sources is often the most difficult part of constructing any beach nourishment. Potential sources for acquiring sand can include commercial upland sand pits, nearshore sources such as mining from the shoals at Mitchells Cut or San Bernard River, and dredged material[1] (Coastal Tech 2010). The feasibility of utilizing sand from these sites corresponds to the proximity of the sites to the project area to reduce mobility costs, quality of sand, and other factors.

The Port of Bay City owns a sand pit containing at least 600,000 cu yd of coarse sand (median grain size D50 = 1.0 mm) available for a beach fill project. Because the sand is much coarser than the native material, less will be needed to achieve a 100 ft berm width. Profile response would also vary from the natural beach; a feature to be evaluated during Phase 2. Detailed design in Phase 2 will determine if this quantity is sufficient for the initial nourishment, although it almost certainly would not be sufficient for multiple nourishment projects. The coarser sand is also likely to stay within the project area longer than finer sand. There may be environmental or social limitations on using coarse sand for beach fill.

Regional considerations and enhancement

Beach nourishment provides sand to the littoral system, benefiting the entire region. Sand eroded from the nourishment area is transported to adjacent beaches providing continued benefits to the region after the fill has been eroded from the target area. It is possible that Mitchell's Cut would fill in and close or that Cedar Lakes Pass would shoal from seasonal reversals in net longshore transport.

Cost

Beach nourishment is typically the least costly alternative for short term mitigation of beach erosion. However, the maintenance cost can be much higher than other methods of beach stabilization. Even if the cumulative cost of beach nourishment over 50 years is less than other alternatives, the uncertainty in the future cost of sand and fuel as well as the available

[1] Discussion with Cliff Dominey and Michelle Matte (SWG O&M) indicate that material from the GIWW in this region would not likely provide suitable beach fill. Further investigation will be conducted during Phase 2.

funding makes it difficult to consider beach nourishment as a viable long term solution.

5.1.3 Alternative 2: Single groin east of Mitchells Cut plus beach fill

This alternative includes beach nourishment described in Alternative 1 and a single long groin placed adjacent to Mitchells Cut to the east. The intent of this layout is to increase the interval between required maintenance nourishment through the use of a single groin placed to the east of Mitchells Cut, and also reduce the likelihood for closure of Mitchells Cut. Figure C-2 shows the beach nourishment with the single groin layout. An unrealistically long groin was included in this alternative to demonstrate maximum trapping capacity. It is important to note that any groin project at Sargent Beach will require periodic maintenance resulting from cross-shore movement of sediment during storms.

Shoreline change

Addition of the single groin improves performance of the beach fill to the east of Mitchells Cut from the cut to approximately Station 54+000, a distance of over 10,000 ft (Figure 30 shows net shoreline change). This extreme example shows the limits of influence of a single groin. Increased erosion occurs to the west of Mitchells Cut as the groin traps nearly all transport to the west. A shorter more permeable groin would allow some bypassing while still improving fill performance to the east, although improvement would not extend as far to the east. Without nourishment, the region of accretion extends about 5,000 ft to the east, a feature exaggerated by model results that do not appear to be accurate.

Although performance is increased near Mitchells Cut, overall nourishment is still required about every three years. Limiting the maintained area to the area east of Mitchells Cut would extend the nourishment interval. The renourishment interval would depend on how far to the east a beach is desired.

Environmental considerations

Environmental considerations discussed for the beach nourishment alternative are also relevant for this alternative in addition to considerations for the single groin. Sediment being transported into Mitchells Cut would be reduced by addition of the single groin. The groin may act as a single jetty,

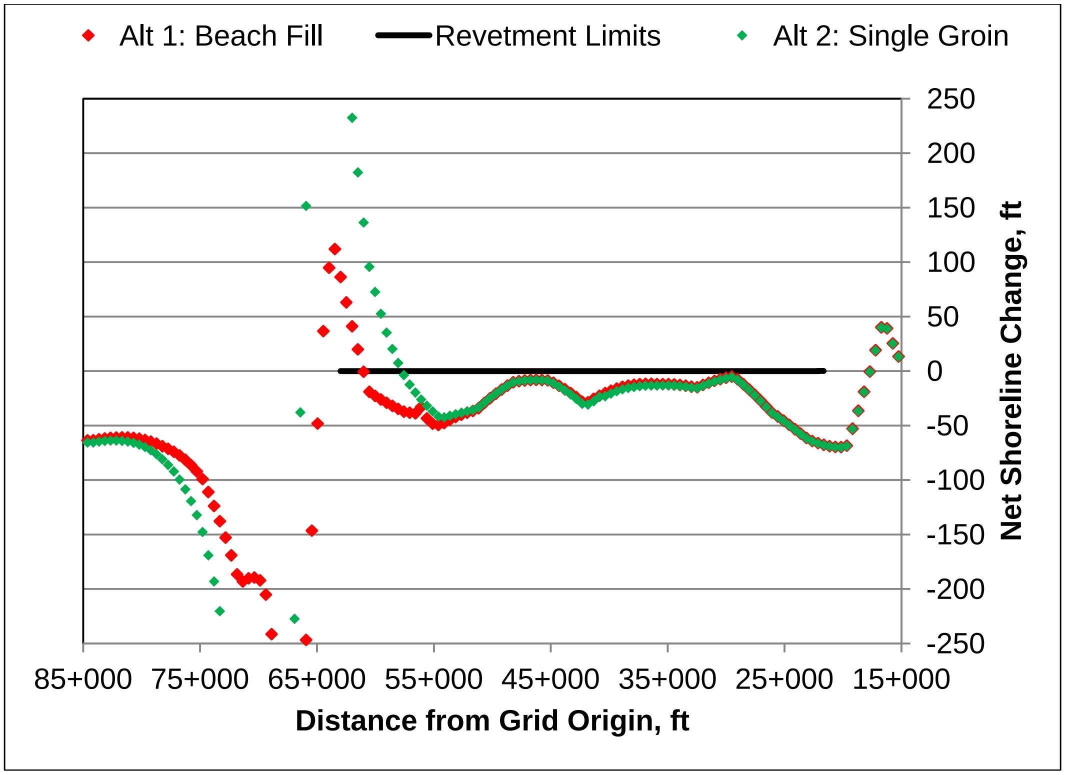

Figure 30. Sargent – Alt. 2: Net shoreline change after 5 years for long groin at Mitchells Cut and three million cu yd of beach fill.

forming a deeper, more stable channel. Further consideration for construction of the single groin should include minimizing disturbance to vegetated areas in the upland environment. Turbidity could be increased by excavation or placement of material during construction.

Habitat protected

Habitat would be created with the widening of the beach as well as benthic habitat from the construction of the single groin. Habitat protected includes habitat seaward of the advanced shoreline as previously discussed.

Storm damage vulnerability

Storm damage resiliency would be improved with the addition of sand to the system through the beach nourishment project. The single groin acts to hold sand at the target beach, increasing the likelihood that a wide beach will be present when a tropical storm occurs. The groin does not reduce cross-shore transport, a key process during storms at this site, and could increase cross-shore transport immediately adjacent to the structure through formation of rip currents. The stone structure should be designed

to resist storm waves and currents. This alternative leaves the beach almost as vulnerable to storm induced erosion as the beach fill only alternative.

Constructability

The same concerns for finding beach quality sand discussed for Alternative 1 exist for this alternative. The groin can be built from land, providing relatively easy construction access. The same methods and materials employed at the new MCR jetty would be employed to construct the groin. Geotechnical investigations are required to enable design. Weaker subsurface soils may make this alternative less feasible.

Regional considerations and enhancement

The model results show that the groin may exacerbate erosion on the west side of Mitchells Cut and that negative impacts are primarily constrained to the Mitchells Cut area. Increased erosion in this area could lead to destabilization of Mitchells Cut and should be analyzed in greater detail if this alternative is preferred. Refinement of groin length and permeability could reduce these impacts.

Cost

Initial nourishment cost would include the same considerations discussed for the beach fill alternative. Maintenance cost would be slightly lower since the groin helps hold sand in place as discussed above. Initial cost of the groin would be higher than the beach nourishment cost. This alternative would likely only be less costly over a 50 year project life if a very small area to the east of Mitchells Cut is included as a part of long-term maintenance of the project area.

5.1.4 Alternative 3: Groin field plus beach fill

This concept consists of a groin field extending the entire length of Sargent Beach plus the beach fill discussed in Alternative 1. The average length of each groin is 600 ft, with groins approximately 1,800 ft apart. The full plan includes a total of 28 groins with a combined total length of over 16,500 ft. The concept includes the full beach nourishment presented in Alternative 1 and is intended to extend the longevity of the nourishment. This approach is

scalable; capable of being applied over shorter lengths of beach with fewer groins and less nourishment.

Gross transport is much larger than net transport in this region, a key indicator that groins will not function well. The dominance of cross-shore transport processes also presents a problem for groin design. Groins can enhance cross-shore transport by creating offshore currents adjacent to the groin (rip currents). Many different configurations were tested with GenCade. The most effective of the configurations tested is shown in Figure C-3.

Shoreline change

The groin field increases the longevity of the nourishment. Figure 31 shows the net shoreline change after five years. Except for two small areas near Stations 29+000 and 46+000, the fill is eroded within five years. The groin field, in its present configuration, causes accretion on the east side of Mitchells Cut and erosion to the west. Additional design modifications are necessary to help balance this effect; however it is likely that some bypassing or other structural modifications may be necessary to prevent destabilization of Mitchells Cut. The groin field increases the longevity of the beach fill project to four – five years. Storms will likely control renourishment intervals at this site, making it unlikely that any groin configuration will result in a practical renourishment interval longer than five years.

Environmental considerations

The same environmental considerations presented for the beach nourishment alternative are applicable to this alternative. Some additional environmental considerations for the groin field include but are not limited to downdrift erosion, increased turbidity during construction, and reduction in viable habitat for the migrating Piping Plover. In addition, the placement of multiple groins on the beach could restrict the access point for nesting sea turtles and currents generated at the seaward point of the structure could inhibit turtles from coming onshore, although USACE (1993) reports that turtles avoid Sargent Beach.

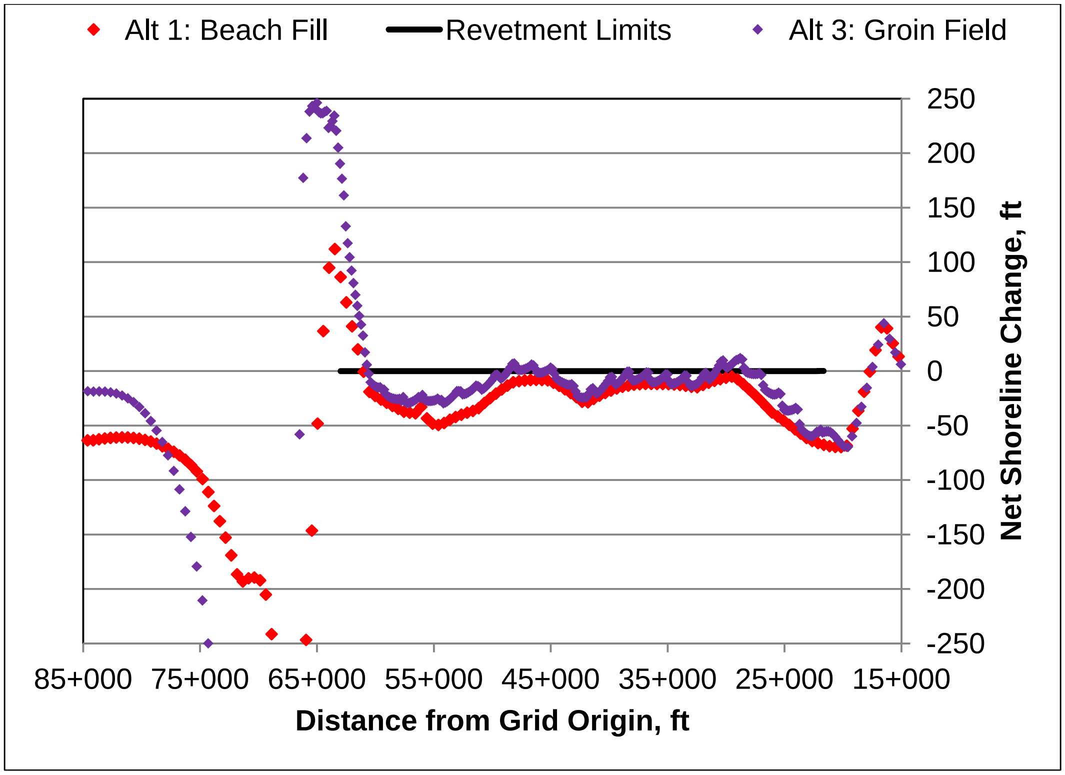

Figure 31. Sargent – Alt. 3: Net shoreline change after 5 years for groins plus three million cu yd beach fill.

Habitat protected

The addition of sand to the system through beach nourishment will create habitat as discussed in previous sections. The groin field could also provide benthic habitat as well as provide habitat for fish populations (USACE 1989).

Storm damage vulnerability

Storm damage resiliency would be improved with the addition of sand to the system through the beach nourishment project. The groins act to hold sand at the target beach. Groins do not reduce cross-shore transport, a key process during storms at this site, and could increase cross-shore transport immediately adjacent to the structures. The stone structures should be designed to resist storms waves and currents.

Constructability

The same concerns for finding beach quality sand discussed for Alternative 1 exist for this alternative. The groins can be built from land, providing

relatively easy construction access. The same methods, and likely materials, employed at the recent MCR jetty would be employed to construct the groin. Connection of the groins to tie into the existing revetment may require special attention during design and construction. Geotechnical investigations are required to enable design. Weaker soils may make this alternative less feasible.

Regional considerations and enhancement

The model results show that the groin field may exacerbate erosion on the west side of Mitchells Cut and that negative impacts are primarily constrained to the Mitchells Cut area. Increased erosion in this area could lead to destabilization of Mitchells Cut and should be analyzed in greater detail. Refinement of groin length and permeability could reduce these impacts.

Cost

Initial nourishment cost would include the same considerations discussed for the beach fill alternative. Maintenance cost could be lower since the groins hold more sand in place as discussed above, although structures will likely require maintenance after large storms. Initial cost of the groin field would be much higher than the previously discussed alternatives.

5.1.5 Alternative 4: Breakwaters

This concept consists of segmented breakwaters extending the entire length of Sargent Beach; layout is shown in Figure C-4. This alternative does not include beach fill, although this could be included in the design or to increase constructability of these offshore structures. Breakwaters function by reducing wave energy reaching the beach. They can be placed far offshore creating a tranquil area between the breakwaters and shore, directly onshore to function as a headland breakwater system, or locations in between. Designing breakwaters to enable natural bypassing is more complicated than for groins, with greater risk of inadvertently trapping more sediment than intended. The added risk and cost associated with breakwaters is offset by the benefit of reducing cross-shore transport. Controlling wave energy reaching the beach is the only way to address the uncertainty in our knowledge of coastal processes associated with the unique sediments at this site.

The average length of each breakwater for this conceptual layout is 220 ft and the gap width is about 330 ft. This configuration was initially based on the breakwaters installed at Holly Beach, LA. The full plan includes a total of 82 segments with a cumulative structure length of over 17,600 ft. Nourishment is not included in the initial concept to help offset cost. Depending on the final design layout, it may be necessary to place fill during construction to help reduce post construction impacts to adjacent shorelines or to increase constructability by building a “sand bridge” to the constructed features. This approach is scalable; capable of being applied over shorter lengths of beach with fewer breakwater segments. Building a shorter breakwater to demonstrate this alternative may help refine design while providing protection to a smaller area.

Shoreline change

Shoreline and transport response to the structures is controlled by the cross-shore position of the breakwaters, permeability of the structures, gap width, ratio of structure to gap length, depth at which structures are placed and many other factors. The sensitivity of the layout to the many variables and complexity of processes at the site preclude accurate GenCade results for this conceptual layout. Therefore, a typical layout that has been successful on the Gulf of Mexico coast was applied for this analysis. More detailed analyses will be required during Phase 2 if a breakwater alternative is selected.

Detached breakwaters can form one of three shoreline responses: no response, which occurs if the structures are placed too far offshore or allow too much wave energy to pass through; a salient, in which the shoreline accretes to the lee of the structure but does not attach to the structure; and a tombolo, in which the shoreline attaches to the structure. Design goals for beaches protected by detached breakwaters are typically either salients, which allow alongshore transport to continue in the lee of the structures, or tombolos, which stop alongshore transport but provide more local beach protection. A project that initially builds a tombolo can be modified by removing stone to increase wave transmission and result in salient formation. A structure initially forming a salient may be modified by increasing its length or height, potentially creating a future tombolo. Offshore distance is another variable but it is very difficult to move a rubble mound structure once it has been built.

Figure 32 shows net shoreline change after the five year period. Final shoreline position, demonstrating salients on the east end of Sargent Beach, is shown in Figure 33. Shoreline response is similar behind the remaining breakwater sections, not shown. Accretion occurs in the lee of the breakwaters and erosion occurs in the gaps. As a balance is achieved between the eroding and accreting beach, the shoreline position becomes stable. The black line in Figure 32 represents a moving average of the shoreline change, representing the average design shoreline position. The model results show that this alternative results in a stable beach over most of the reach, although the shoreline between the salients may intersect the revetment and erosion may be increased to the west of Mitchells Cut.

Environmental considerations

Environmental considerations for the breakwater alternatives include but are not limited to downdrift erosion, modification of the beach shape, and increased turbidity during construction. Breakwaters could restrict access for nesting sea turtles and currents generated in the gaps could inhibit turtles from coming onshore, although USACE (1993) reports that turtles avoid Sargent Beach.

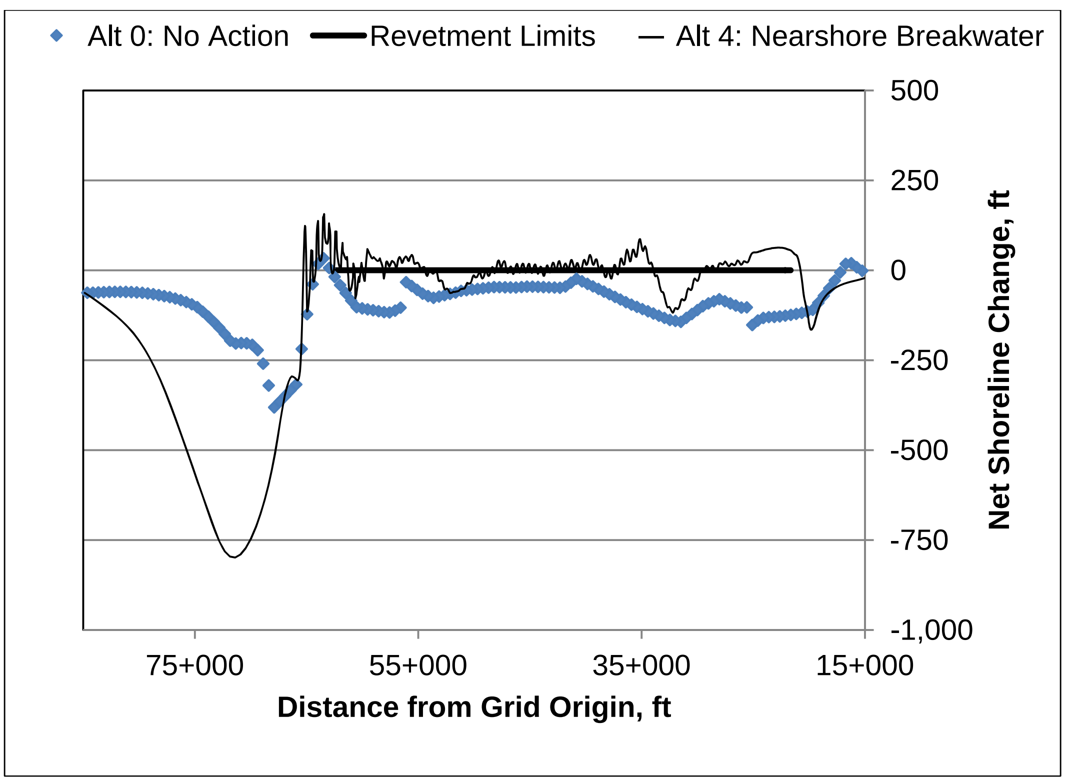

Figure 32. Sargent – Alt. 4: Net shoreline change after five years with detached breakwaters.

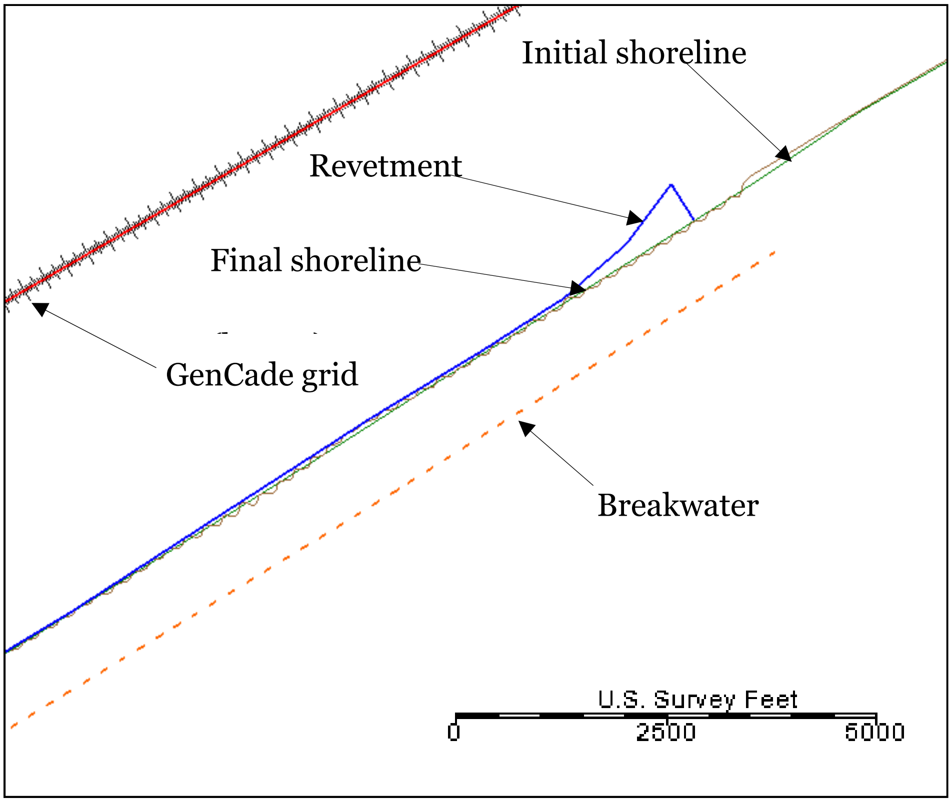

Figure 33. GenCade calculated shoreline after five years for Sargent – Alt 4 detached breakwaters.

Habitat protected

This alternative protects the entire existing Sargent Beach area.

Storm damage vulnerability

Breakwaters provide the greatest storm damage resiliency to the target area of the alternatives considered. The stone structure should be designed to resist storms waves and currents.

Constructability

Depending on the cross-shore location of the breakwaters, the structure may be built from land or water. Modifying the cross-shore location will result in design changes. Rough seas can complicate construction from water, so it may be advantageous to design the structures close enough to land to enable land based construction equipment. A sand bridge to the construction depth would facilitate equipment access. Geotechnical

stability of the soils nearshore is uncertain and may impact breakwater placement or design options.

Regional considerations and enhancement

The model results show that the breakwaters may exacerbate erosion to the east and west. Increased erosion could lead to destabilization of Mitchells Cut and should be analyzed in greater detail. Refinement of breakwater layout will be attempted to reduce these impacts, for example, by building structures at the downdrift end of the project area further offshore, with shorter lengths, or at lower elevations to decrease their effectiveness and allow more sand to transport downdrift.

Cost

Construction cost for this alternative is the greatest of the alternatives considered. Even though the total length of structure is only slightly longer than the groin field, the cost per linear foot will be higher because the average depth of the structure will be greater, leading to a greater volume of stone per linear foot. Choosing to construct the breakwater in shallower water would reduce cost. It will also likely be more difficult to construct the breakwaters, increasing construction time and cost. Maintenance cost will likely be the lowest of the alternatives considered so far and should only include structure repair as a result of storm damage or settlement.

5.1.6 Alternative 5: Transition breakwaters

This concept consists of segmented breakwaters placed to stabilize the beach at both ends of the revetment; layout is shown in Figure C-5. The intent is to manage the increased rate of erosion anticipated as the revetment begins to be exposed while providing some natural beach and protection for beaches to the east and west of Sargent Beach. This alternative maintains the existing beach on both ends of Sargent Beach but sacrifices the beach in between, which is the area of highest erosion.

The average length of each breakwater for this conceptual layout is 220 ft and the gap width is about 330 ft. The full plan includes a total of 35 segments with a cumulative structure length of over 7,400 ft. Nourishment is not included in the initial concept to help offset cost. Depending on the final design layout, it may be necessary to place fill during construction to help reduce post construction impacts to adjacent shorelines. This

approach is scalable; capable of being applied over shorter lengths of beach with fewer breakwater segments. Building a shorter breakwater to demonstrate this alternative may help refine design while providing protection to a smaller area.

Shoreline change

Shoreline and transport responds in the same way discussed in the previous section. Figure 34 shows net shoreline change after the five year period. The red line in Figure 34 represents a moving average of the shoreline change, showing the average design shoreline position. Figure 35 plots the final shoreline position on the east end of Sargent Beach; note that the shoreline intersects the revetment beyond the breakwaters. Only the eastern section of breakwater is plotted in Figure 35; shoreline response is similar at the western section.

The model results show that this alternative results in a stable beach behind the breakwaters, although the shoreline between the salients may intersect the revetment. Between the two breakwater sections, the shoreline recedes to the revetment within five years. The present configuration increases updrift and downdrift erosion.

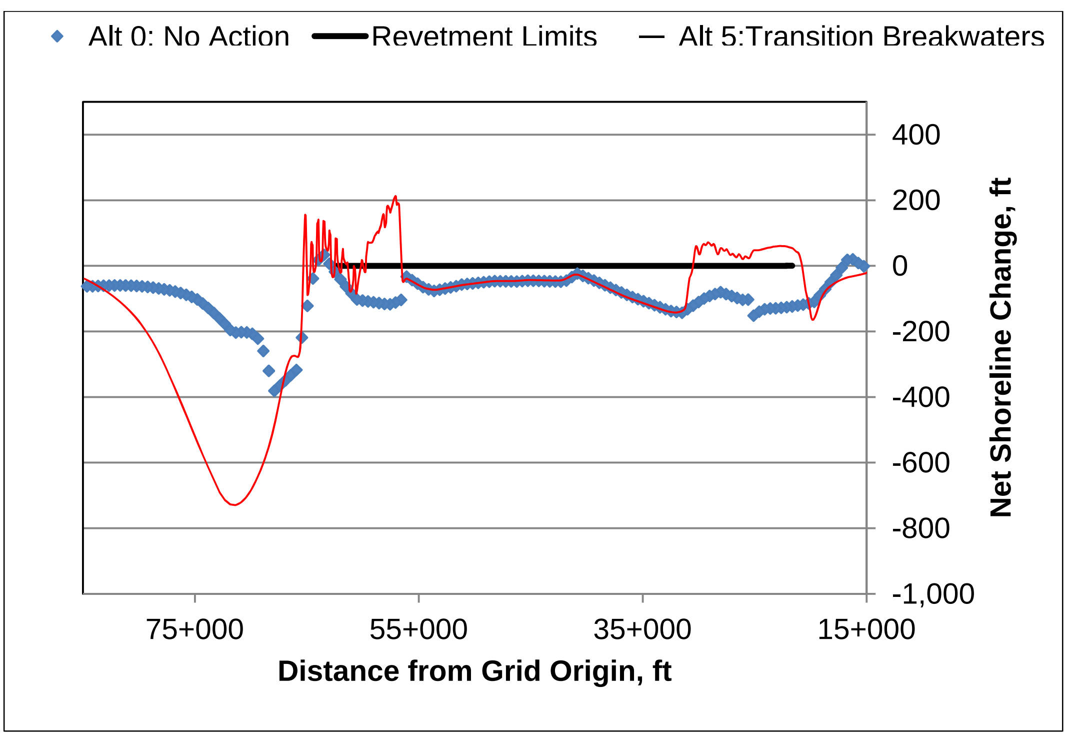

Figure 34. Sargent – Alt. 5: Net shoreline change after five years with two sets of detached breakwaters at the project boundaries.

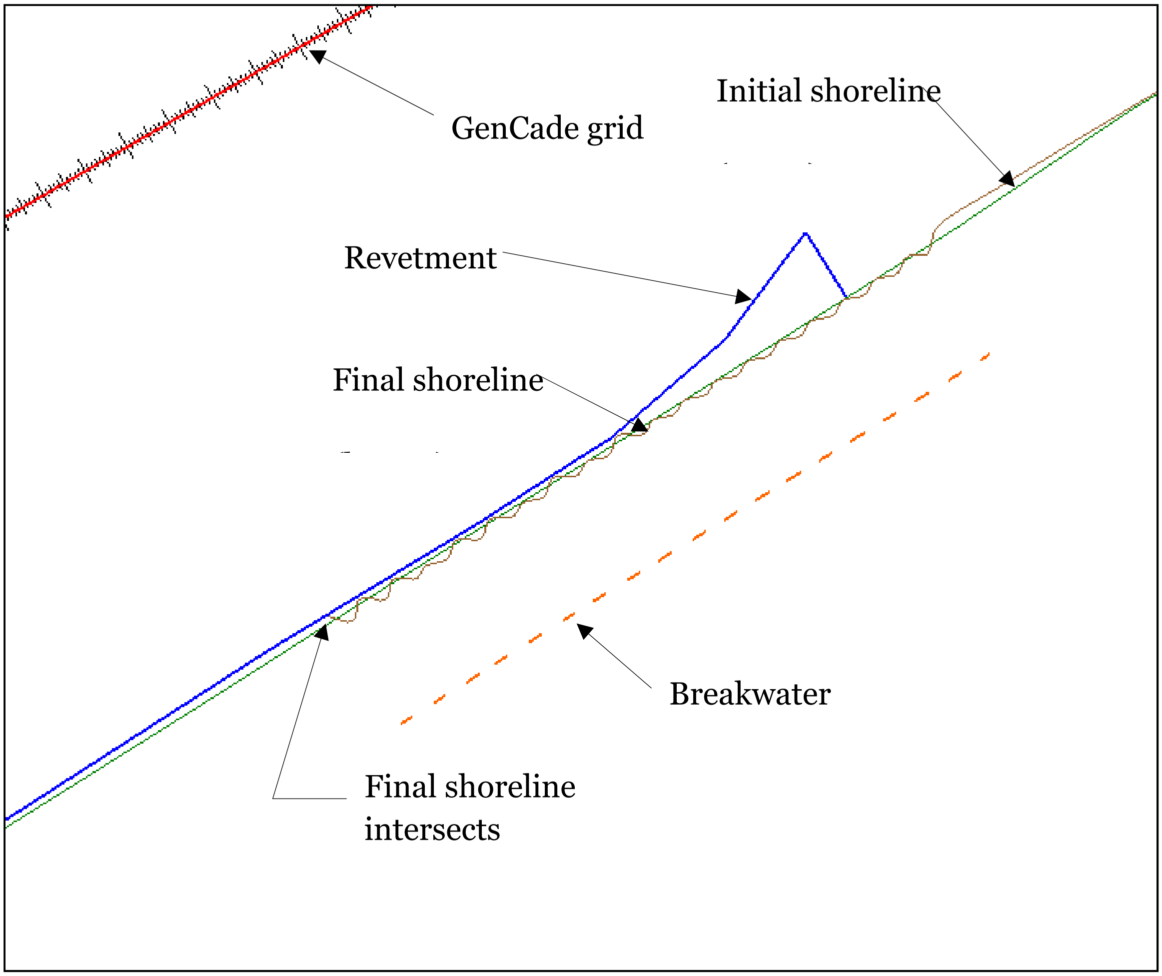

Figure 35. GenCade calculated shoreline after five years for Sargent East – Alt 5.

Environmental considerations

Environmental considerations for the breakwater alternatives include downdrift erosion, modification of the beach shape, and increased turbidity during construction. Breakwaters could restrict access for nesting sea turtles and currents generated in the gaps could inhibit turtles from coming onshore, although USACE (1993) reports that turtles avoid Sargent Beach. This alternative includes allowing the revetment to become exposed, the consequences of which were addressed in USACE (1993).

Habitat protected

This alternative protects the beach to the east and west ends of Sargent Beach, although it sacrifices the beach in between.

Storm damage vulnerability

Breakwaters provide the greatest storm damage resiliency to the target area of the alternatives considered. The stone structure should be designed to resist storm waves and currents. Overtopping of the revetment will be greater in the areas between the two sets of segmented breakwaters after the revetment has become exposed. This design protects the project boundaries but the beach in between would be exposed to storm damage.

Constructability

Depending on the cross-shore location of the breakwaters, the structure may be built from land or water. Modifying the cross-shore location will result in design changes. Rough seas can complicate construction from water, so it may be advantageous to design the structures close enough to land to enable land based construction equipment. Geotechnical stability of the soils nearshore is uncertain and may impact breakwater placement or design options.

Regional considerations and enhancement

The model results show that the breakwaters may exacerbate erosion to the east and west and will result in exposure of the existing revetment between the breakwaters. Increased erosion could lead to destabilization of Mitchells Cut and should be analyzed in greater detail. Refinement of breakwater layout will be attempted to reduce these impacts.

Cost

Construction cost for this alternative is much less than the previous breakwater alternative. Placing the structures closer to shore would reduce cost. Maintenance cost will likely be the lowest of the alternatives considered so far and should only include structure repair as a result of storm damage or settlement.

5.2 Matagorda Peninsula

5.2.1 Alternative 0: No Action

The baseline alternative is to take no action. All other alternatives will be compared to this scenario. Since there is no planned modification, the

existing conditions Figures shown in Appendix A are representative and no additional layout figure is included in Appendix C.

Shoreline change

The GenCade model developed in Chapter 5 was applied to analyze shoreline change. The July 2011 shoreline was specified as the initial shoreline and the five year analysis period described in Chapter 5 was run to calculate shoreline change. Figure 36 plots the net shoreline change after five years. GenCade calculated erosion directly to the east of MCR is much greater than historically observed and likely not representative of future erosion. Increased erosion may be attributed to distribution of bypassing and configuration of the 2011 shoreline. Therefore, these results should be used comparatively to infer project influence on shoreline change.

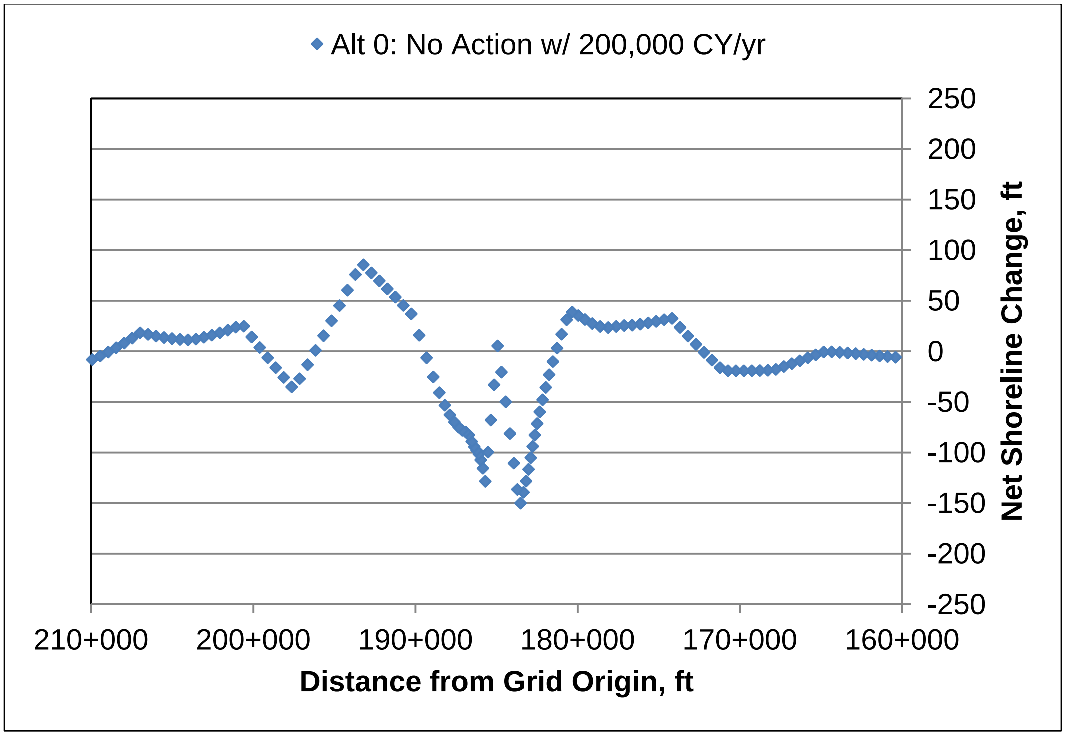

Figure 36. Matagorda – Alt. 0: Net shoreline change after five years.

The bypassing rate around MCR is modified to represent the recommended bypassing rate from Kraus et al. (2008) of 200,000 cu yd/year. Shoreline change immediately adjacent to the inlet has been extremely sensitive to dredging here and will likely continue to be in the future. Considering the increased scarcity in federal funding for dredging shallow draft channels, the selected alternative should include some type of bypassing allowance.

Discussion

The greatest influence on shoreline change here is management of sediments at MCR. Design of the recently constructed jetty at MCR is based on the assumption that bypassing will be conducted (Kraus et al. 2008). Ensuring that bypassing occurs is paramount to continued shoreline stability in the vicinity of MCR.

5.2.2 Alternative 1: Groin and bypassing system

A series of groin configurations were analyzed to help widen the beach east of MCR. A single groin located on the west side of the area of concern appears to be sufficient to increase beach width, although the exact limits of desired increase need to be further refined.

Sediment bypassing around MCR is important to prevent flanking of the west jetty and to help manage accretion on the east side of the inlet. Therefore, an installed bypassing system capable of moving varying amounts of sediment is recommended in addition to the groin.

It is important to note that this concept will advance the shoreline; however, without dune and vegetation management, it will not create a wider dry beach. Since the existing beach is presumably in equilibrium, the dune and vegetation will advance with the shoreline, maintaining the dry beach width. Management actions, such as grading the upper beach, will be required to increase the dry beach width as the shoreline advances.

Shoreline change

Figure 37 plots net shoreline change after five years near MCR for the No Action alternative and the single groin alternative with variable amounts of sediment bypassing around MCR. The results show that shoreline change at the target area is very sensitive to bypassing at MCR. It is anticipated that system performance will vary depending on annual variability in sediment transport conditions at the site.

Environmental considerations

Environmental considerations would include increased turbidity during construction of the groin, and disruption of habitat in area of sediment inflow/outflow from the bypassing system.

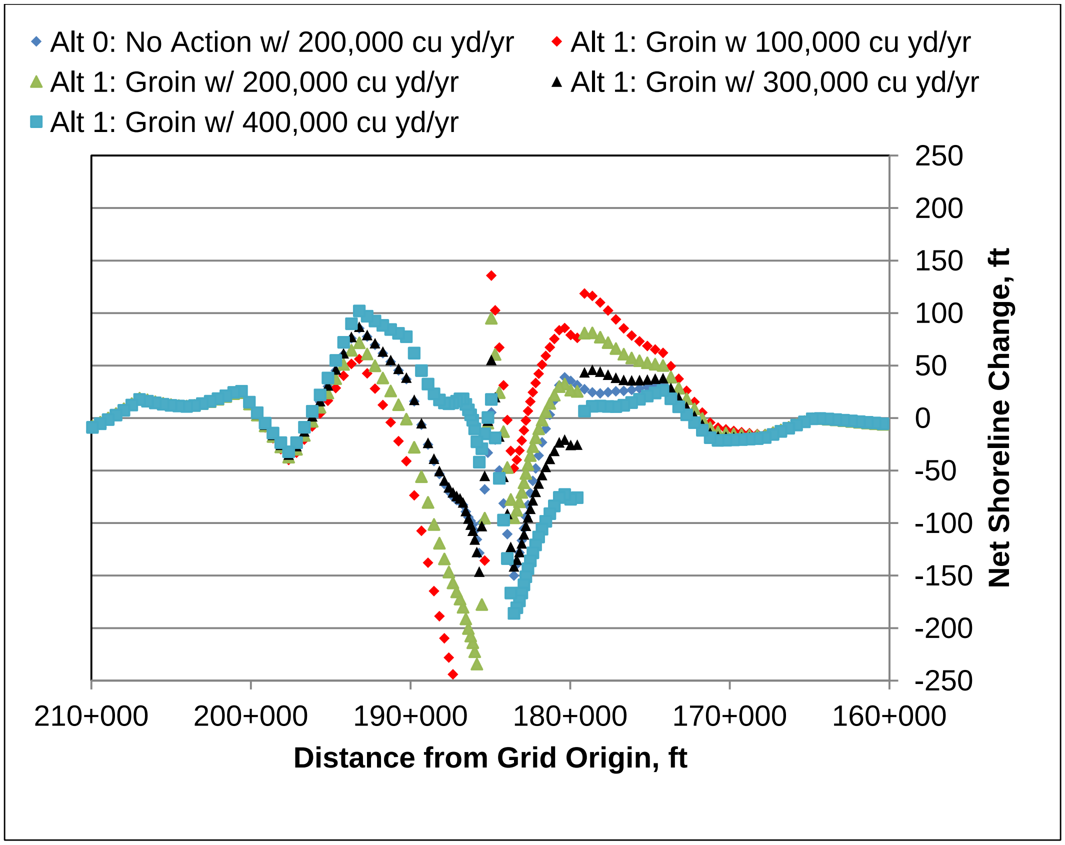

Figure 37. Matagorda – Alt. 1: Net shoreline change after five years for single groin and various bypassing rates at MCR.

Habitat protected

Benthic habitat would be created from the construction of the single groin and habitat would be created west of the MCR where sediment is placed from the bypassing system. The wider beach east of the new groin would provide increased protection for landward habitat.

Storm damage vulnerability

The single groin would help provide a wider beach to the east of the groin increasing storm damage protection. The bypassing system will help prevent flanking of the MCR west jetty through placement of sand downdrift of the inlet.

Constructability

The groin would be built from land applying similar construction techniques used at MCR in 2010. The bypassing system consists of an

installed pump, control systems and pipelines. The system could use the existing pipeline across the Colorado River Navigation Channel.

Regional considerations and enhancement

The bypassing system would provide critically needed sediment to the beach west of MCR, reducing erosion.

Cost

The cost associated with this alternative includes acquiring material to construct the groin and implementing a sediment bypassing system. Annual maintenance and operations cost would vary based on storm activity and average annual volume of sediment transported.

5.2.3 Alternative 2: Breakwaters and bypassing system

Preliminary investigation into breakwaters was conducted. Because of the clear performance advantages of groins at this site (i.e. there is a clear net transport direction, lower erosion rate, and lower dependence on cross-shore processes) further analysis of breakwaters is not presented in this report. A properly placed breakwater will create the same shoreline response caused by the groin; however the short breakwater will not provide the same storm damage reduction benefits achieved with the longer series of breakwaters and would be installed purely to function as a groin.

5.3 Alternative comparison

The preceding section described the conceptual alternatives and presented results of analyses and a qualitative discussion of feasibility. This section compares the alternatives to determine which should be analyzed in greater detail in Phase 2.

5.3.1 Sargent Beach

The goal at Sargent Beach is to prevent erosion of beach sediments in the target area (shown in Figures 1 and A-1). To help assess which alternatives are most likely to meet that goal, a matrix comparing the six alternatives based on eight criteria was developed. Information provided in the preceding sections was applied to rank the various alternatives. Each alternative is ranked from 0 to 10, with 0 being the worst and 10 being the

best expected outcome. At this stage of the project, the ranking is qualitative in many of the categories, based on experience with similar projects. The eight categories for comparison are described below:

- Reduces/stops beach erosion: How well an alternative is expected to combat beach erosion in the target area. Value in this category is based on GenCade results and engineering judgment.
- Protects/enhances habitat: How well an alternative is expected to protect or enhance habitat within the target area.
- Storm damage vulnerability – structural: How likely it is that the proposed structure will be damaged or destroyed in a storm.
- Storm damage vulnerability - protected areas: How likely it is that the structure will protect habitat and infrastructure during a storm. Includes consideration that beach fill may not be present when a storm occurs.
- Construction cost: Expected relative cost of initial construction, with values of 10 being the least costly, and 0 the most costly.
- Maintenance cost: Expected relative maintenance cost, including cost of renourishment and storm damage; similar scale as above.
- Constructability: How likely it is that the structure can be constructed. Includes the impact of scarcity of future sand resources.
- Enhances/degrades regional performance: Ranks the alternatives based on regional value. A value of 5 implies no benefit or impact to regional performance, values of 6-10 represent a regional benefit and values of 0-4 indicates some impact to adjacent beaches. To help assess which alternatives are most likely to meet that goal, a matrix (Table 18) comparing the six alternatives based on eight criteria was developed.

Uncertainty associated with transport and erosion of the mixed sediments along with the low net to gross transport ratio make it unlikely that existing analysis techniques will conclusively show that groins will provide the desired result. Although it is possible that placing sand over the cohesive sediment will reduce the erosion rate which could modify the order of preferred alternatives, analysis techniques necessary to quantify this are well outside the budget constraints of this project. This uncertainty is reflected in the higher rank for breakwaters than groins and beach nourishment.

Table 18. Decision matrix for Sargent Beach alternatives.

		Reduces/stops beach erosion	Protects/enhances habitat	Storm damage vulnerability - structural	Storm damage vulnerability - protected areas	Construction cost	Maintenance cost	Constructability	Enhances/degrades regional performance	Total Score
0	No Action	0	0	10	0	10	10	10	5	45
1	Beach Fill	6	8	2	4	9	0	1	10	40
2	Single Groin East of Mitchells Cut w/ Beach Fill	6	8	4	5	7	2	7	4	43
3	Groin Field w/ Beach Fill	7	8	6	6	2	5	7	4	45
4	Breakwaters	10	10	10	8	0	7	6	2	53
5	Transition Breakwaters	9	6	10	7	5	8	6	2	53

5.3.2 Matagorda Peninsula

The goal on Matagorda Peninsula is to halt erosion and increase beach width over the target area. The model results indicated that a single groin would likely meet this goal, but that success would be highly dependent on bypassing operations at MCR. Since Federal funding for dredging at shallow draft navigation channels is limited and future funding uncertain, no alternative was suggested without an installed bypassing system. Table 19 presents the qualitative decision matrix, showing that the groin with a bypassing system is preferred. Various levels of bypassing without the groin were tested as well; however sufficient shoreline advance at the target area was not achieved without the groin.

It is possible that the new east jetty and addition of Braggs Cut could modify the transport regime. Performance of any shoreline stabilization system near MCR will be dependent on transport around the inlet; therefore monitoring should be conducted to quantify transport at MCR before finalizing any design.

Table 19. Decision matrix for Matagorda Peninsula alternatives.

		Reduces/stops beach erosion	Protects/enhances habitat	Storm damage vulnerability - structural	Storm damage vulnerability - protected areas	Construction cost	Maintenance cost	Constructability	Enhances/degrades regional performance	Total Score
0	No Action	0	0	10	0	10	10	10	2	42
1	Groin with Bypassing System	8	8	8	6	8	8	8	10	64

6 Summary and Conclusions

Sargent Beach has experienced the highest erosion rates on the Texas Coast prompting study into structural methods to protect beach habitat. In addition, a three mile reach of beach to the east of MCR requires stabilization. This report documents the first phase of a two part study to identify structural and non-structural methods to meet these goals.

The first part of this report focuses on physical processes in the region culminating in a conceptual sediment budget and one line model of shoreline change for the region. Key findings from that investigation are as follows:

- Sargent Beach
    - This is among the fastest eroding coastlines in Texas. Analysis of recent data indicates extreme rates of erosion are continuing
    - Net transport is small relative to gross transport
    - Uncertainty remains in the processes responsible for the extreme erosion at Sargent Beach
        - Cohesive sediments eroded are lost from the active beach system
        - Cross-shore transport is a critical pathway for erosion
        - Sediment is trapped at inlets
        - These processes are not well quantified, making it difficult to predict future erosion of material different than the existing sediment
    - There is not sufficient sand in the system to maintain regional shoreline position

- Matagorda Peninsula
    - There is a strong net transport direction to the west
    - Bypassing is critical to stabilizing shoreline position on both sides of MCR
    - Recent construction of the new east jetty at MCR and Braggs Cut may lead to a new equilibrium that might change the dependence on bypassing

Understanding of physical processes gained through this investigation was applied to develop potential alternatives to combat erosion. The alternatives were analyzed with respect to shoreline change, habitat protection, storm damage vulnerability, cost, constructability, and potential to impact or enhance regional shoreline stability. This analysis resulted in a decision matrix used to help determine which alternatives should be analyzed in greater detail during Phase 2.

The recommended alternatives at Sargent Beach consist of segmented breakwaters (Sargent – Alt: 4 & 5). Breakwaters enable modification of the forcing process causing erosion (waves), a process that is well understood, making it more likely to manage erosion successfully. They also provide the greatest potential for avoiding costly future nourishment. The high cost of protecting the entire reach led to creation of a second breakwater alternative to protect just the beach at the ends of the revetment, which should reduce the cost by over half. Only protecting the west end between FM 457 and Mitchells Cut would further reduce the cost.

The preferred alternative east of MCR on Matagorda Peninsula is a single groin with an installed bypassing system at MCR to automatically manage downdrift shoreline position (Matagorda – Alt 1). This system should provide the increased beach width needed on Matagorda Peninsula and help stabilize shoreline position on both sides of MCR. Any bypassing system considered should be managed adaptively to account for variability in the transport regime. Final design of this alternative should be deferred until sufficient monitoring of coastal processes at MCR has been conducted to verify any changes resulting from construction of the new east jetty and Braggs Cut.

Although many different structural configurations were tested, there was no obvious configuration that incurred benefits to either area as a result of the adjacent project. Bypassing at MCR provides a substantial regional benefit providing needed sediment to beaches to the west that would otherwise be impounded by the jetties. The recommended project at Sargent Beach appears likely to cause increased erosion to the west of Mitchells Cut, reducing sediment supply to the west and potentially destabilizing Mitchells Cut or increasing the potential for breaching at Brown Cedar Cut. This concern should be carefully addressed during Phase 2.

6.1 Phase 2 tasks

Phase 2 of the project is intended to provide detailed local scale modeling and refinement of regional scale processes to enable the functional design of the selected alternatives. Analyses will include quantification of regional benefits and potential impacts of the proposed structural solution. The following list includes tasks to be conducted during Phase 2:

- Data collection analysis
    - Beach surveys measured in September 2011
    - Water level logger deployed in September 2011
    - Aerial photograph flown in July 2011
- Additional data collection may include:
    - Geotechnical investigation
    - Currents
    - Cross-shore sediment sampling
- Refine regional sediment budget using recommendations presented in Chapter 3
- Coastal process modeling
    - Refine GenCade model
        - Include longer time scales
        - Analyze iterative modification of alternative layouts
    - Apply Coastal Modeling System (CMS)
        - Analyze alternatives
        - Verify stability of Mitchells Cut
    - Investigate cross-shore transport with SBEACH or other appropriate model
- Preliminary structure design
- Revisit conceptual feasibility analysis
    - Use preliminary design to develop preliminary cost estimates and quantify areas impacted
- Document results

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Appendix A: Overview and Shoreline Change Figures

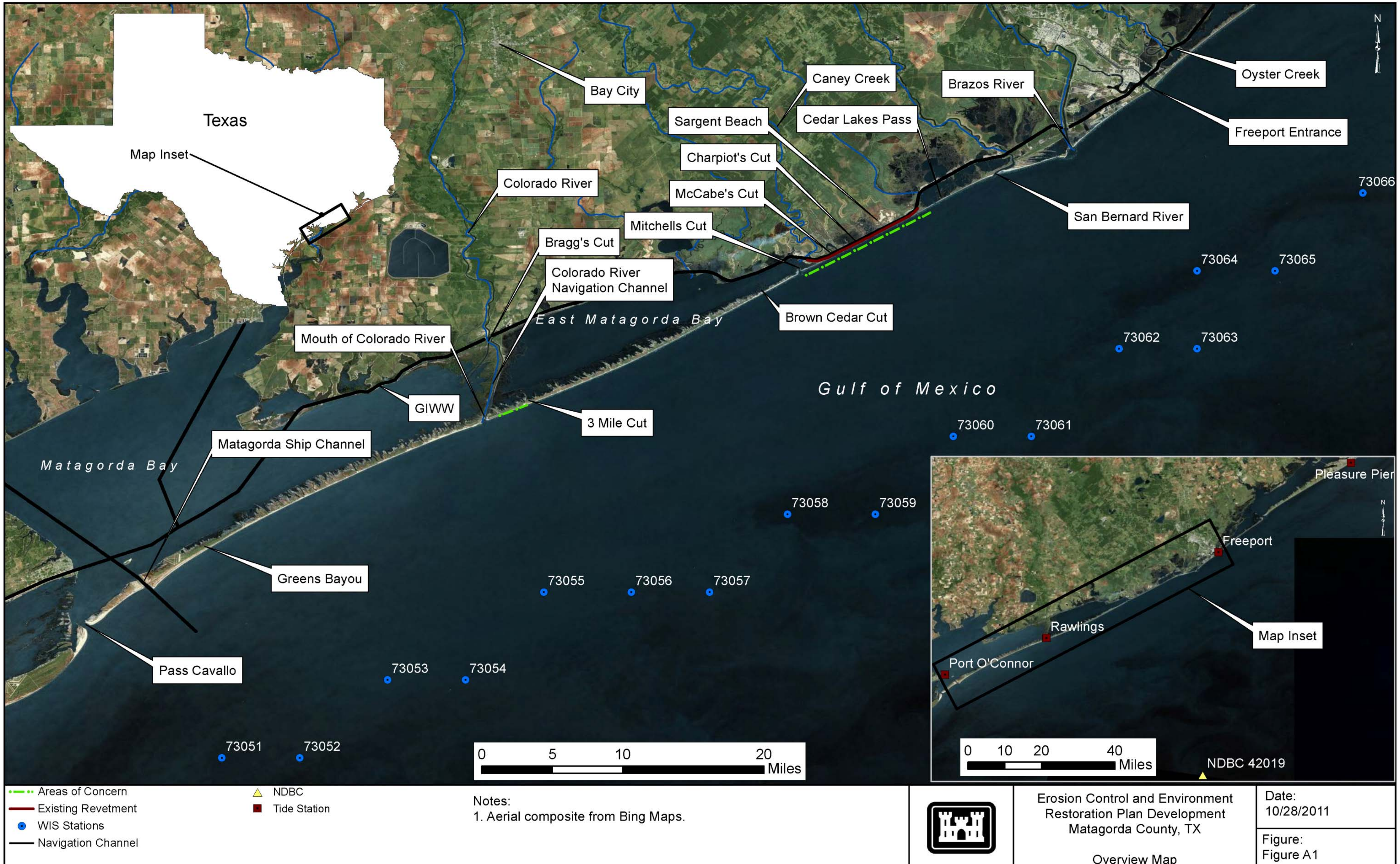

Figure A1. Erosion control and environmental restoration plan development, Matagorda County, TX – Overview map.

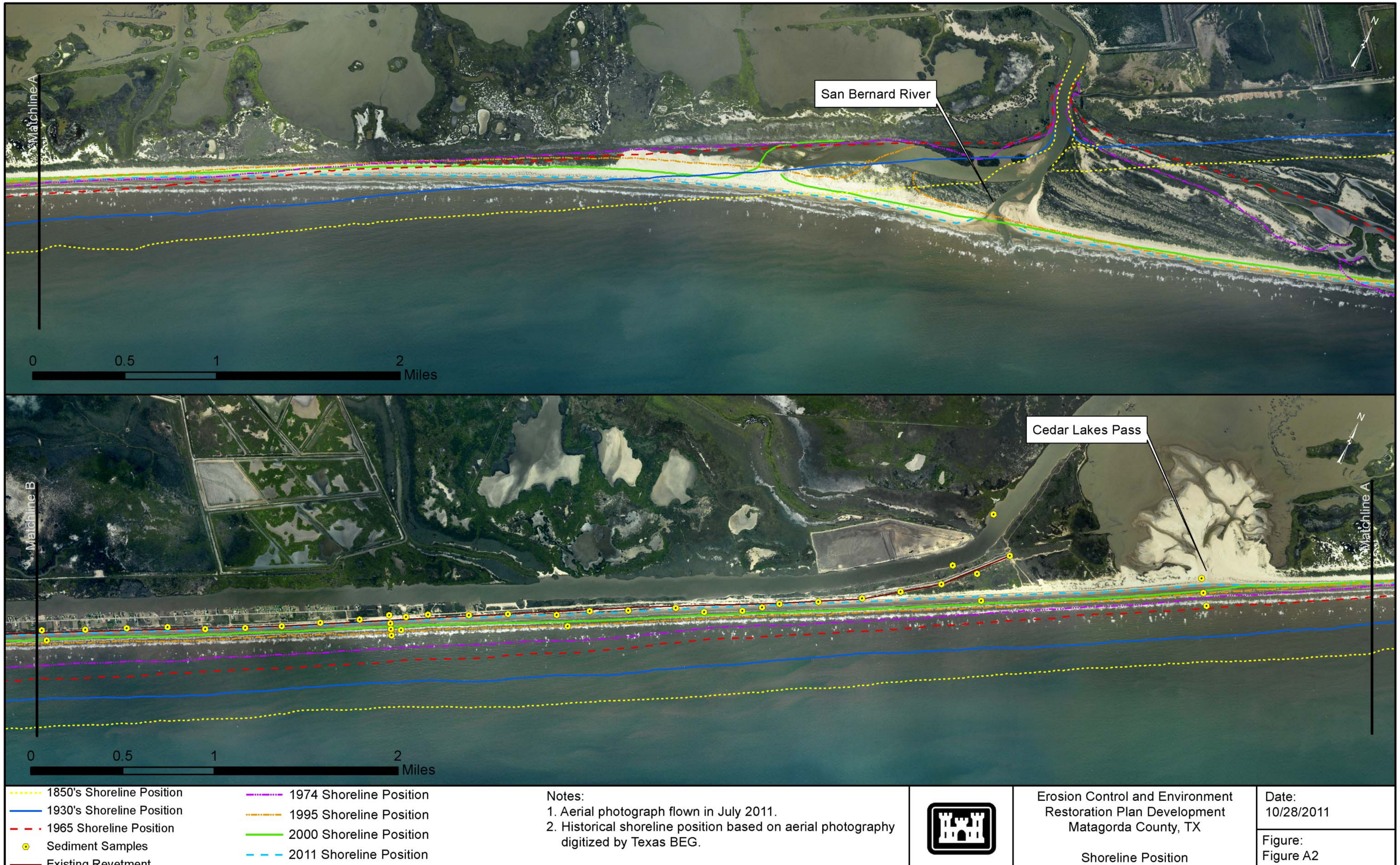

Figure A2. Erosion control and environmental restoration plan development, Matagorda County, TX – Shoreline position.

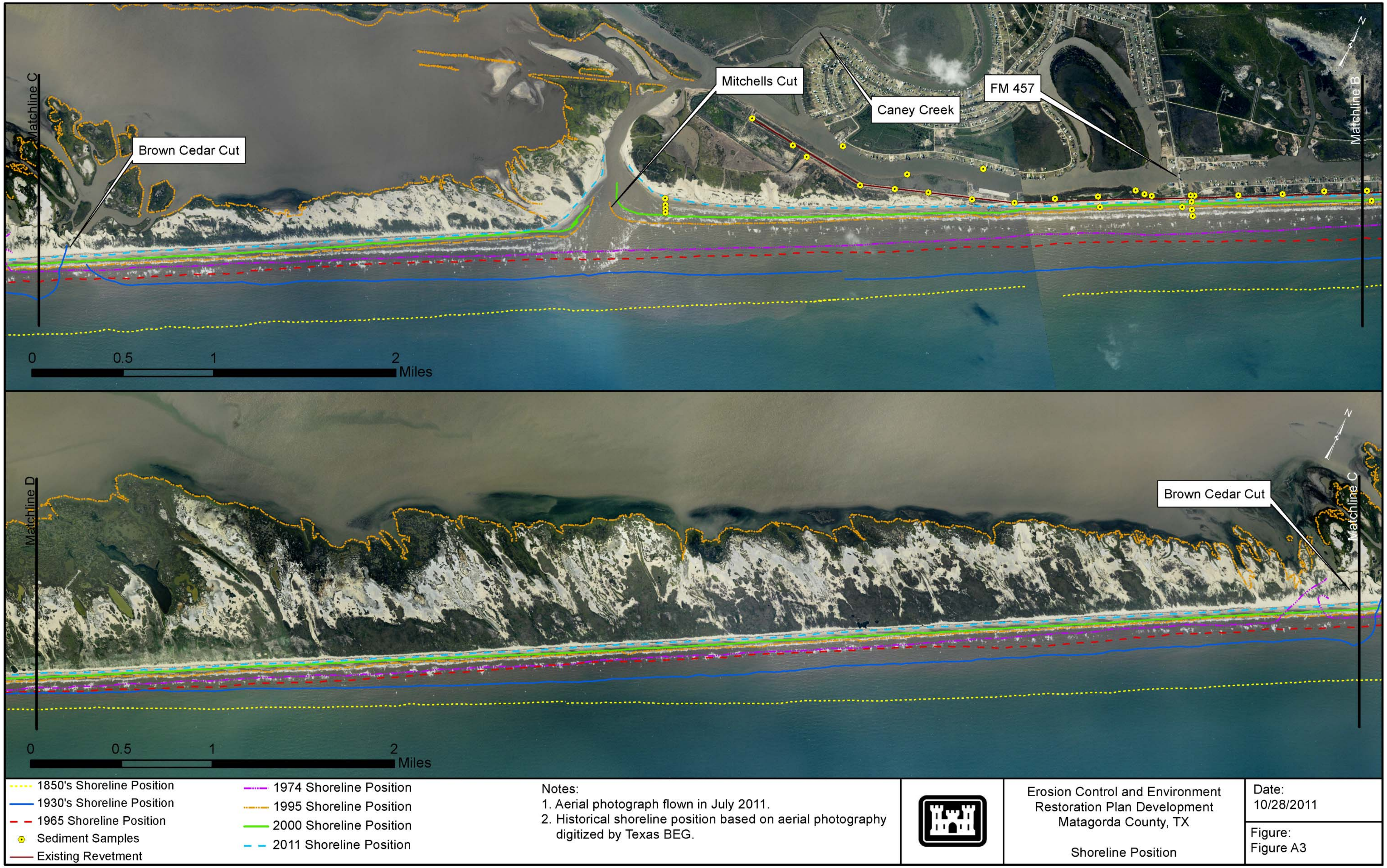

Figure A3. Erosion control and environmental restoration plan development, Matagorda County, TX – Shoreline position.

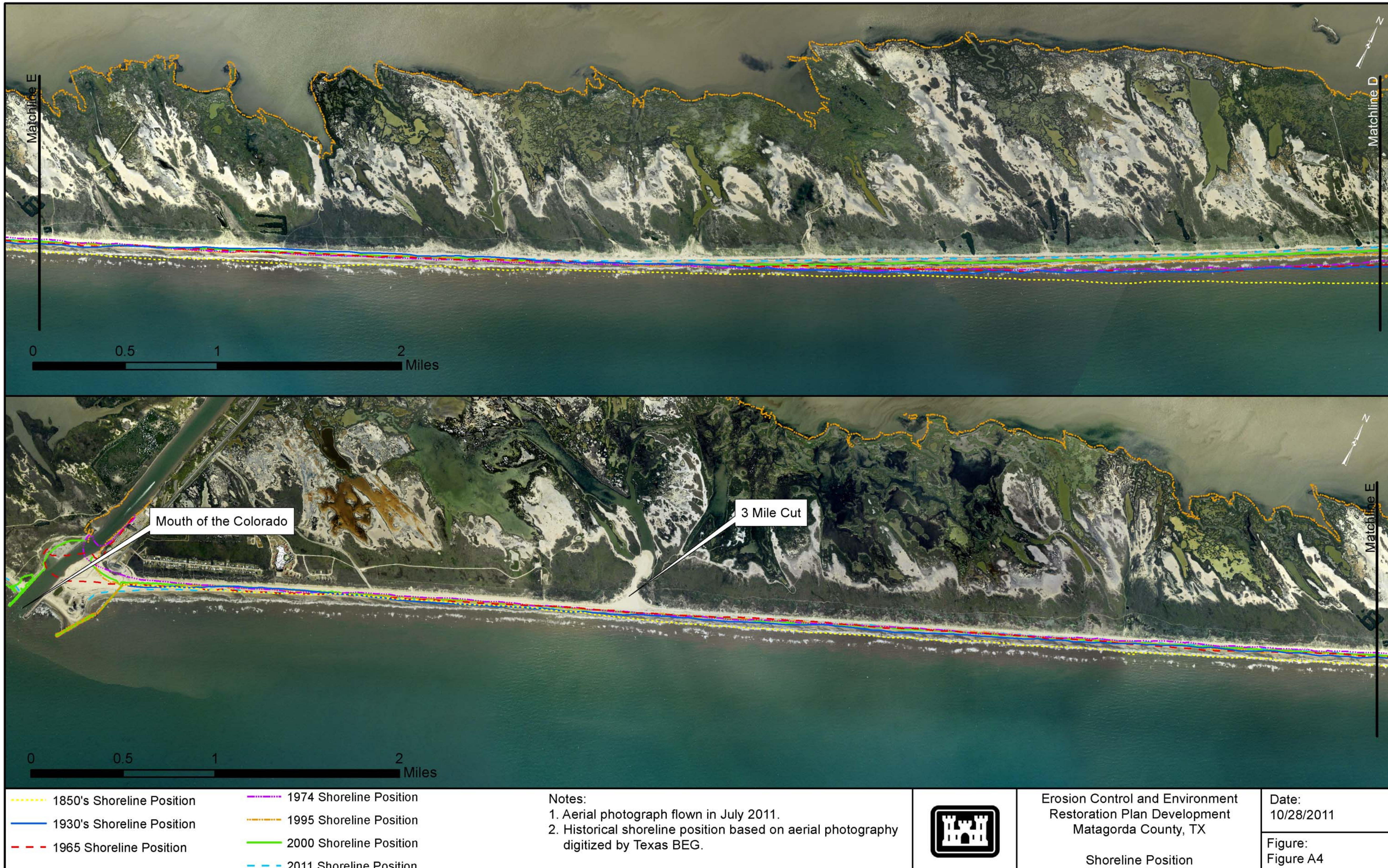

Figure A4. Erosion control and environmental restoration plan development, Matagorda County, TX – Shoreline position.

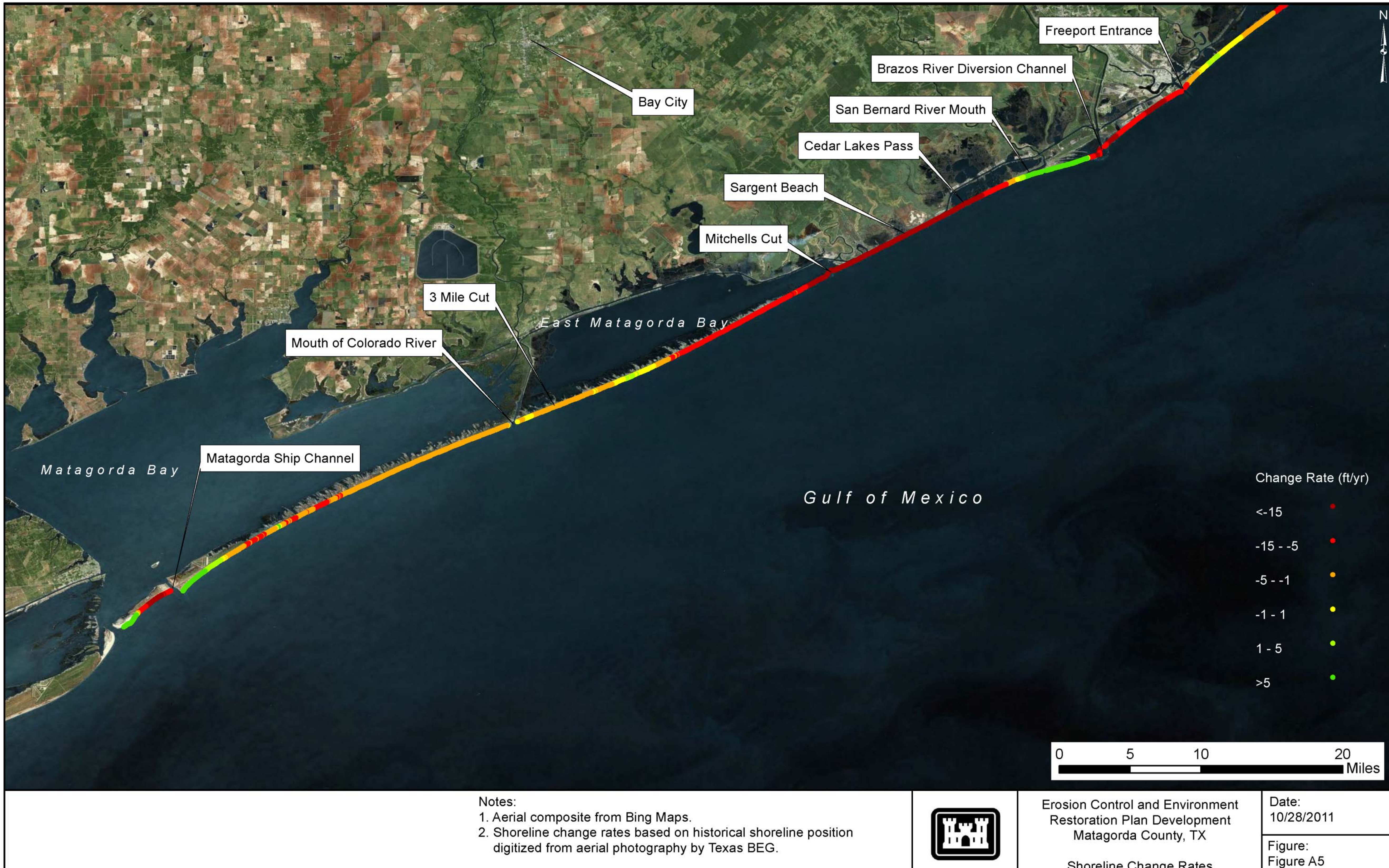

Figure A5. Erosion control and environmental restoration plan development, Matagorda County, TX – Shoreline change rates.

Appendix B: Sediment Budget Figures

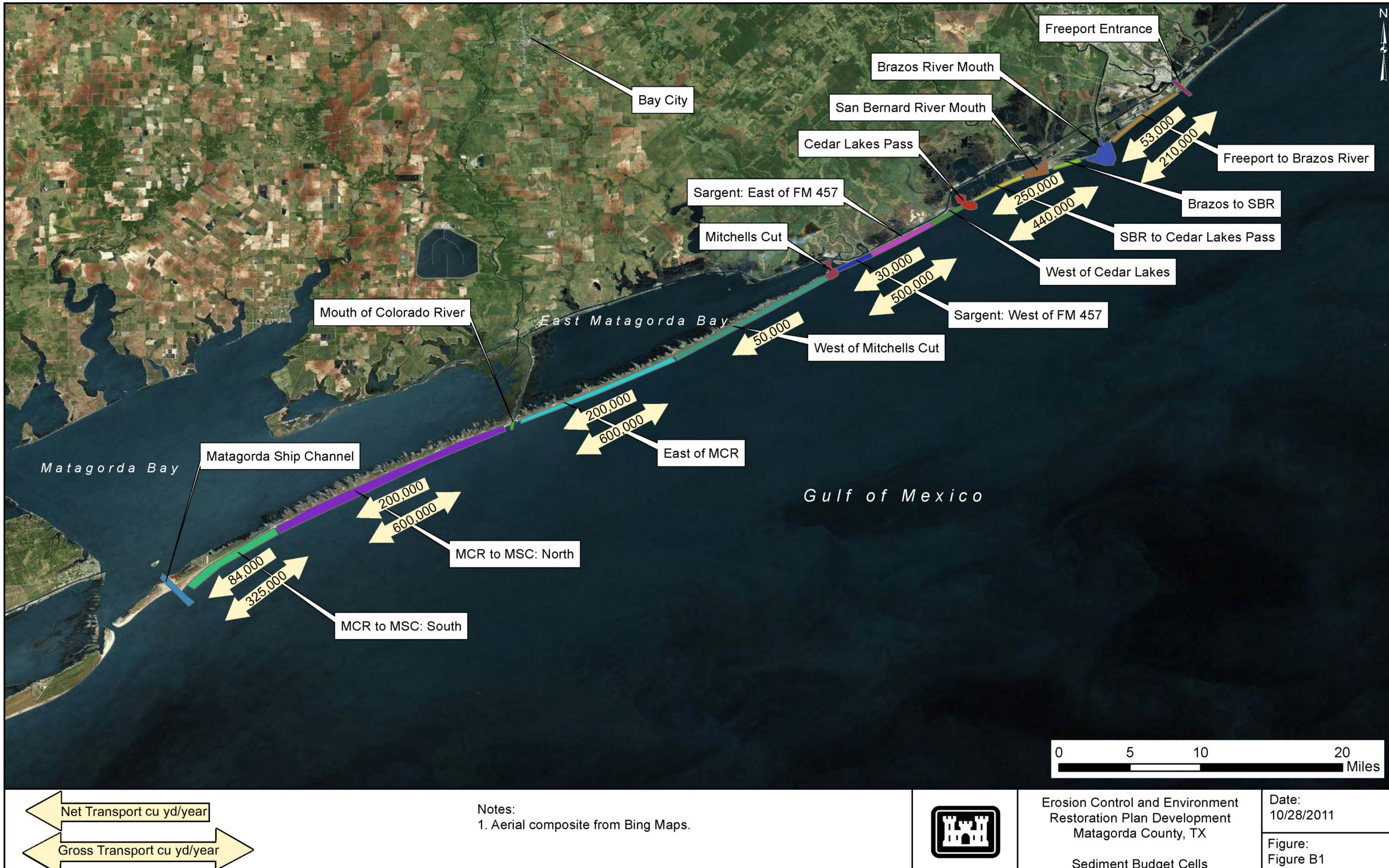

Figure B1. Erosion control and environmental restoration plan development, Matagorda County, TX – Sediment budget cells.

Appendix C: Preliminary Alternative Layout

Existing Revetment

Beach Fill

Notes:
1. Aerial photograph flown in July 2011.
2. Beach fill layout based on added design berm width of 100 ft.

Erosion Control and Environment Restoration Plan Development: Matagorda County, TX

Sargent Beach-Alt1: Beach Fill

Date: 10/28/2011

Figure: Figure C1

Figure C1. Erosion control and environmental restoration plan development, Matagorda County, TX – Sargent Beach-Alt 1: Beach fill.

Figure C2. Erosion control and environmental restoration plan development, Matagorda County, TX – Sargent Beach-Alt 2: Beach fill.

Figure C3. Erosion control and environmental restoration plan development, Matagorda County, TX – Sargent Beach-Alt 3: Groin field.

Existing Revetment Breakwaters	Notes: 1. Aerial photograph flown in July 2011.		Erosion Control and Environment Restoration Plan Development: Matagorda County, TX Sargent Beach-Alt 4: Breakwaters	Date: 10/28/2011 Figure: Figure C4

Figure C4. Erosion control and environmental restoration plan development, Matagorda County, TX – Sargent Beach-Alt 4: Breakwaters.

Figure C5. Erosion control and environmental restoration plan development, Matagorda County, TX – Sargent Beach-Alt 5: Trans. Breakwaters.

Figure C6. Erosion control and environmental restoration plan development, Matagorda County, TX – Matagorda-Alt 1: Groin & bypass.

Appendix D: Historical Aerial Imagery

Figure D1. Historical aerial imagery.

Figure D2. Historical aerial imagery.

Figure D3. Historical aerial imagery.

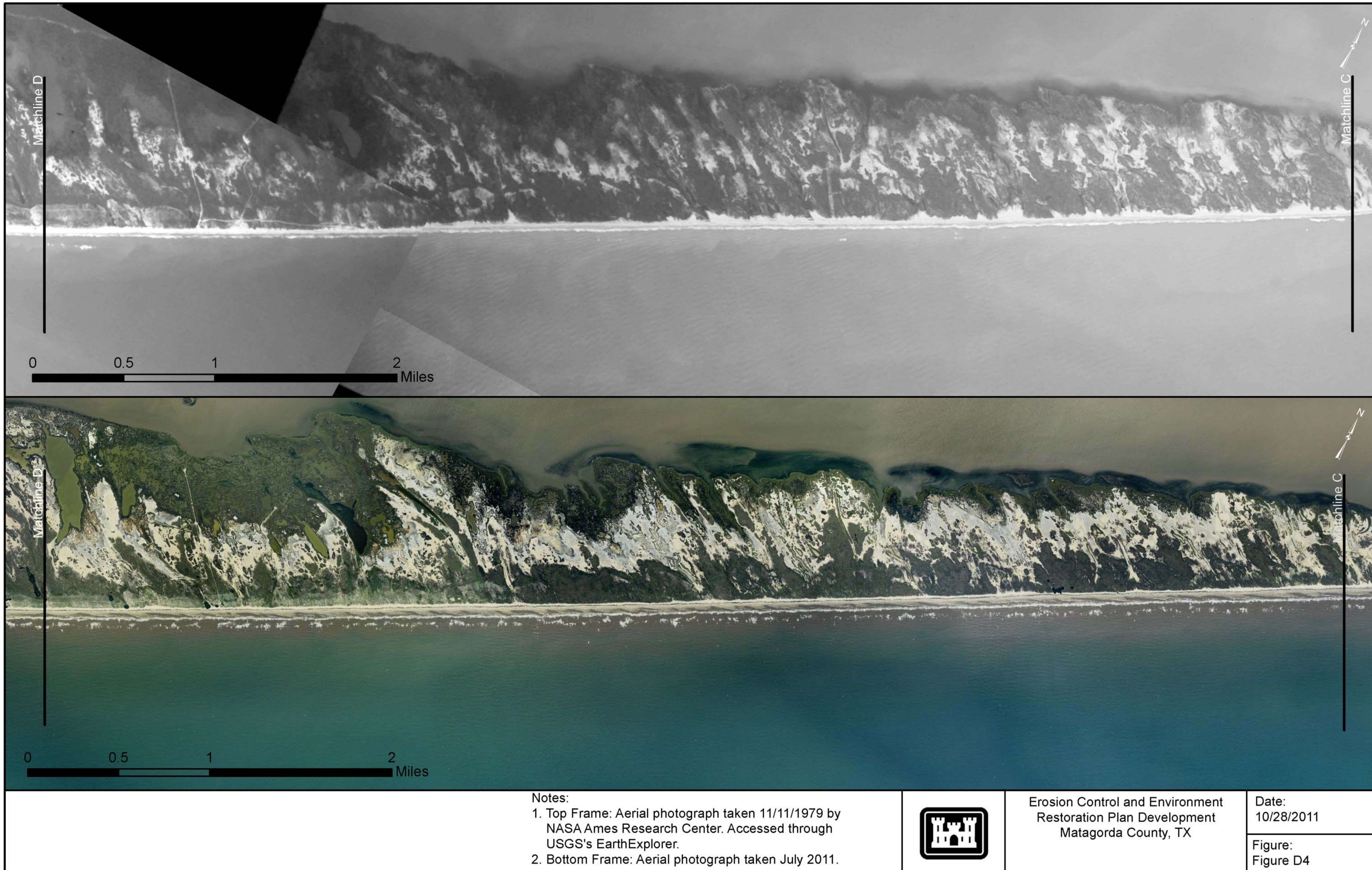

Figure D4. Historical aerial imagery.

Figure D5. Historical aerial imagery.

Figure D6. Historical aerial imagery.

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14. ABSTRACT
This report documents the investigation of coastal processes and development of conceptual alternatives to reduce beach erosion at two sites in Matagorda County. Sargent Beach has experienced the greatest erosion rates on the Texas Coast, prompting study into structural methods to protect beach habitat. Additionally, the three miles of beach to the east of the Mouth of the Colorado River is a candidate for structural stabilization. The proximity of the two project areas provided an opportunity to consider processes on a regional scale in an effort to improve regional shoreline stability and further understanding of regional processes.

Sargent Beach is comprised of cohesive sediment overlain by a thin veneer of sand. It is located between an ephemeral inlet to the east and a flood relief inlet to the west. The region includes two major river diversion projects, an eight mile long revetment at Sargent Beach, and many other engineering modifications influencing transport. Because of the complex site, an investigation into coastal processes was conducted to determine alternative development. Understanding of physical processes developed during this investigation was applied to develop potential solutions to reduce erosion, including beach nourishment, groins, breakwaters, and installed bypassing systems.

15. SUBJECT TERMS

Beach erosion	Breakwater	Groin	Texas Gulf Coast
Beach nourishment	Coastal structures	Sediment budget	
		Shoreline change	

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